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Guidance for Development of a Flight Simulator Specification

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Interim Report for December 2006 to May 2007

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Air Force Research Laboratory
Human Effectiveness Directorate
Warfighter Interface Division
Cognitive Systems Branch
Wright-Patterson AFB OH 45433-7022

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FOR THE DIRECTOR

//SIGNED//

DANIEL G. GODDARD
Chief, Warfighter Interface Division
Air Force Research Laboratory

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14. ABSTRACT
A long-standing problem in the acquisition of flight simulators has been the clear communication of requirements through the specification process. There are numerous reasons for this, including obfuscation by technical jargon, fragmentation of requirements within a specification, and a human inclination to adopt 'cut and paste' approaches which may reflect the requirements of a precedent system more than those of the current system. In an attempt to address these problems, this document was developed as basis for a tool in the form of a generic flight simulator specification that will guide specification development for a diverse range of flight simulator applications. Each generic specification paragraph includes recommendations and rationale for specification language, verification, and options. Guidance reflects the requirements established by civil regulatory agencies—such as the International Civil Aviation Organization's criteria for the qualification of flight simulators—as well as those unique requirements related to military applications. This generic guidance specification is embodied in a software format that makes it relatively easy to use—so as to encourage its use. When it is used, the documents produced will reflect the high degree of standardization imposed by this guidance specification. It will provide a clear alternative to less-disciplined cut-and-paste approaches. Standardized format and vocabulary will help avoid misplaced information and inconsistent interpretations. Localization and integration of requirements will minimize conflicts.

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PREFACE

This document was developed in-house by Dr. Edward A. Martin of the Cognitive Systems Branch, Warfighter Interface Division, Human Effectiveness Directorate of the Air Force Research Laboratory (AFRL/HECS), Wright-Patterson Air Force Base, Ohio 45433-7022, for the period December 2006 to May 2007. This effort supported Work Unit 7184D199.

1. SCOPE. This specification establishes the requirements and associated verification methods for __1__.

RATIONALE
This specification can be used for any simulation device (simulator) used to train aircrews or to support mission rehearsal requirements. It is intended to cover the entire spectrum of devices from Level 2 Flight Training Devices to Level D Flight Simulators (or Weapon System Trainers) for both airplanes and helicopters.

The types of simulators covered by this specification are:

a. Those simulators that operate in a totally stand-alone mode, providing training to a pilot or complete aircrew. The entire outside world is generated by the simulator. There is one position for each crew member. This specification also addresses the possibility of splitting the crew positions and allowing simultaneous training in independent missions.

b. Those simulators that consist of multiple representations of the same crew position(s) with some central elements. The entire outside world is generated by the simulator. The specification also addresses the possibilities of degraded operation, or loss of one or more crew positions in the simulator.

c. Interactive operation for a or b above. Here the specification only addresses the simulators that would interface to a communication network, it does not attempt to address the overall network.

The specification also allows for simulators that are combinations of a through c above. The simulators may provide complete training for the aircraft or crew position or may train only part of the tasks associated with the aircraft or crew position. Where a single crew position is simulated it is appropriate to replace the term crewmember with the position name such as "pilot" or "navigator".

This guide specification must be tailored for specific applications; tailoring guidance is provided in the "rationale" sections associated with each paragraph. The "requirement guidance" and "verification guidance" sections included in each "rationale" section provide instructions for filling in the blanks of the respective paragraphs with recommended wording. The author of the specific application document may also rewrite a given paragraph, delete it, or add new paragraphs. The rationale section is intended to provide guidance for offeror/contractor use in developing either a System Specification or a Prime Item Development Specification (PIDS), or for government use in developing a Systems Requirement Document (SRD).

"Process guidance" is included in a "rationale" section when appropriate. This guidance discusses items that should be considered in development of the Statement Of Work (SOW), in development of other non-specification documents, or in design reviews.

Requirements Guidance:

1. Fill in blank (1) with device name, nomenclature (if available), and aircraft represented (if applicable).

EXAMPLES
1. SCOPE This specification establishes the requirements and associated verification methods for a Unit Training Device, Nomenclature AN/ALQ-T4, for the F-15 and F-16 Aircraft.

2. APPLICABLE DOCUMENTS. The first-tier references cited in this specification shall be mandatory for use, and lower-tier references shall be for guidance only.

RATIONALE
This requirement is mandated by the "Air Force Plan for Acquisition Reform of Specifications and Standards" dated 7 July 1994.

2.1 Government Documents.

RATIONALE
This is title-only, lead-in paragraph.

2.1.1 Specifications, Standards, and Handbooks. The following specifications, standards, and handbooks of the exact issue shown form a part of this specification to the extent specified herein.

(1): STANDARDS

MILITARY
MIL-STD-454__2__ Standard General Requirements for Electronic Equipment

MIL-STD-882__2__ System Safety Program Requirements

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

__3__

RATIONALE
Requirements Guidance:
This paragraph is required since the list contains documents referenced elsewhere in this specification. The lead-in wording provided is the MIL-STD-490B preferred wording for system and development specifications.

1. In (1), list applicable documents alpha-numerically under each heading. Under each heading, documents shall be grouped by departmental activity (such as Naval Air Systems Command or Air Force Materiel Command). Documents shall be listed by title and identifier (if applicable). [NOTE: Documents already included in the list are referenced by this specification, and must be retained.] Titles shall be taken from the document rather than from an index. Headings shall be listed in the following order:

Specifications
Federal
Military
Program-unique

Standards
Federal
Federal Information Processing
Military

Handbooks, Military

Drawings, Military

Publications
Federal
Military

2. The documents associated with blank 2 are referenced by this specification; DO NOT DELETE THESE FROM THE LIST!!! Include a specific revision level in blanks 2 (normally this would be the latest revision at the time the solicitation package is being assembled).

3. Retain the source statement preceding blank 3. In addition, if Federal Information Processing Standards (FIPS) are listed, place the following parenthetical statement in blank 3:

"(Copies of the Federal Information Processing Standards (FIPS) are available to Department of Defense activities from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094. Others must request copies of FIPS from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161-2171.)"

Otherwise, delete blank 3.

EXAMPLES
Note: This example is to illustrate format only, no recommendation regarding content is intended. For information regarding the requirements and capabilities of different "levels" of "Flight Simulators" and "Flight Training Devices", consult the referenced Air Force Pamphlet AFP 36-2211.

2.1.1 Specifications, Standards, and Handbooks. The following specifications, standards, and handbooks of the exact issue shown form a part of this specification to the extent specified herein.

STANDARDS

FEDERAL

FED-STD-376	Preferred Metric Units for General Use by the Federal Government

MILITARY

MIL-STD-454	Standard General Requirements for Electronic Equipment
MIL-STD-882	System Safety Program Requirements

HANDBOOKS, MILITARY

MIL-HDBK-248	Acquisition Streamlining

PUBLICATIONS, MILITARY

AFP 36-2211	Guide for Management of Air Force Training Systems
ESD-TR-86-278	Guidelines for Designing User Interface Software Available from National Technical Information Service, 5285 Port Royal Road, Springfield VA 22161 NTIS number: AD A177 198

(Unless otherwise indicated, copies of federal and military specifications, standards, and handbooks are available from the Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.)

2.1.2 Other Government Documents, Drawings, and Publications. __1__.

__2__

RATIONALE
Requirements Guidance:

1. If there are applicable Government documents not listed in paragraph 2.1.1, they are to be listed here. In this case, MIL-STD-490B states that the following be placed in blank (1).

"The following other Government documents, drawings, and publications form a part of this specification to the extent specified herein. Unless otherwise specified, the exact issue shown applies to this specification."

Otherwise, put the following into blank (1):

"None."

2. In blank (2), list applicable documents alpha-numerically under each heading. Documents shall be listed by title and identifier (if applicable). Titles shall be taken from the document rather than from an index. Headings shall be listed in the following order:

Other Government Documents
[Department of Transportation Specifications]
[U.S. Department of Agriculture Specifications]
[Et cetera]
Drawings
Publications

Where detailed drawings referred to in a specification are listed in an assembly drawing, it is only necessary to list the assembly drawing.

EXAMPLES
Note: This example is to illustrate format only, no recommendation regarding content is intended. For information regarding the requirements and capabilities of different "levels" of "Flight Simulators" and "Flight Training Devices", consult the referenced Federal Aviation Administration (FAA) Advisory Circulars.

2.1.2 Other Government Documents, Drawings, and Publications. The following other Government documents, drawings, and publications form a part of this specification to the extent specified herein. Unless otherwise specified, the exact issue shown applies to this specification.

OTHER GOVERNMENT DOCUMENTS

AC 120-40C Airplane Simulator Qualification

AC 120-45A Airplane Flight Training Device Qualification

AC 120-63 Helicopter Simulator Qualification

(Applications for copies should be addressed to the U.S. Department of Transportation, Federal Aviation Administration, National Simulator Program, P.O. Box 20636, Atlanta GA 30320)

Engineering Data Compendium, Human Perception and Performance
(Applications for copies should be addressed to the Crew System Ergonomics Information Analysis Center (CSERIAC) Program Office, AL/CFH/CSERIAC Bldg 248, 2255 H Street, Wright-Patterson AFB OH 45433-7022)

2.2 Non-Government Documents. __1__.

__2__

__3__

RATIONALE
Requirements Guidance:

Non-Government standards and other publications, including DOD-adopted documents not normally furnished by the Government, are listed here.

1. If this paragraph is applicable, place the following in blank 1 (this is the preferred wording for system and development specifications, according to MIL-STD-490B):

"The following documents of the exact issue shown form a part of this specification to the extent specified herein."

If not applicable, place the following in blank 1:

"None."

2. In blank 2, list applicable documents alpha-numerically under each heading. Documents shall be listed by title and identifier (if applicable). Titles shall be taken from the document rather than from an index. Headings shall be listed in the following order:

Specifications
Standards
Drawings
Other Publications

In addition, the following parenthetical statement shall follow each individual publication or each group of related publications which may be obtained from a common source:

"(Application for copies should be addressed to the (name and address of the source).)"

3. When applicable, place the following source paragraph in blank 3:

"(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)"

EXAMPLES
Note: This example is to illustrate format only, no recommendation regarding content is intended.

2.2 Non-Government Documents. The following documents of the exact issue shown form a part of this specification to the extent specified herein.

STANDARDS

AMERICAN NATIONAL STANDARDS INSTITUTE (ANSI)

ANSI/AIAA R-004-1992 Recommended Practice for Atmospheric and Space Flight Vehicle Coordinate Systems

(Application for copies should be addressed to the American Institute for Aeronautics and Astronautics, 370 L'Enfant Promenade, SW, Washington, DC 20024.)

AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM)

ASTM E 380 Standard for Metric Practice (DOD adopted)

(Application for copies should be addressed to the American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103-1187.)

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS (IEEE)

IEEE 268 Standard Metric Practice (DOD adopted)

IEEE 1278 Standard for Information Technology--Protocols for Distributed Interactive Simulation Applications

(Application for copies should be addressed to the Institute of Electrical and Electronics Engineers, Inc., 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331.)

INTERNATIONAL STANDARDS FOR THE QUALIFICATION OF AIRPLANE FLIGHT SIMULATORS

(Application for copies should be addressed to the Royal Aeronautical Society, 4 Hamilton Place, London, UK W1V0BQ.)

OTHER PUBLICATIONS

AIRPLANE FLIGHT SIMULATOR EVALUATION HANDBOOK, FIRST EDITION, MARCH 1993

(Application for copies should be addressed to the Evaluation Handbook Coordinator: Mr. Malcolm I. Blackwood, Rediffusion Simulation Ltd., Gatwick Road, Crawlwy, West Sussex, RH10 2RL, ENGLAND.)

(Non-Government standards and other publications are normally available from the organizations that prepare or distribute the documents. These documents also may be available in or through libraries or other informational services.)

3. REQUIREMENTS.

4.2.1. Verification of REQUIREMENTS. Verification of this requirement is not applicable.

RATIONALE

This is a title only paragraph. In stating requirements the simulation device is not treated as a collection of subsystems (e.g., visual, radar, flight, tactics, etc.) as has been traditional. Instead, the specification takes a more natural (real-world) approach. The basic modes and states in which the simulator operates are defined up-front where they clearly apply to all major components. The major components are defined to include the synthetic environment and the simulated air vehicle. The synthetic environment corresponds closely to the world outside the air vehicle. Entities in the environment must be modeled to include properties applicable to all systems (e.g., visual, radar, IR); controls on the environment entities should affect all properties with one action. Similarly, the simulated air vehicle should correspond directly to the aircraft being simulated. A third major component, the cue generators, consist of simulator unique subsystems (image generators, motion system, etc.) that take the synthetic environment defined by various models, data bases, etc., and converts them to cues for the aircrew. A fourth major component

includes all instructor controls, operator controls, displays, etc. The final major component, simulation support, describes the required capabilities to generate databases or other data required to support simulation exercises.

Use of this specification does not require that systems be physically combined (e.g., that databases be physically merged into a single visual or radar database), but it does require that existence of such multiple databases be transparent to a user. Allocation of requirements in this specification to lower level subsystems requires a real systems engineering process, i.e., requirements stated in a given paragraph cannot usually be assigned directly to an individual functional group.

3.1 System Definition.
3.1 Prime Item Definition. The __1__ is intended for use __2__ in __3__ at __4__. It shall comply with all requirements of this specification.

4.2.1.1 Verification of System Definition.
4.2.1.1 Verification of Prime Item Definition. Verification of this requirement is not applicable.

RATIONALE
This paragraph provides a lead-in to the device requirements. Its purpose is to define the intended use of the device -- as a necessary background for further development of the specification. Requirements of the specification should be consistent with the intended use statement.

Requirements Guidance: *Fill in blanks as follows:*

1. *Fill in device name.*

2. *Fill in who uses and their initial qualifications.*

3. *Fill in task(s) to be accomplished.*

4. *State where the device is to be used.*

EXAMPLES
Example 1. Prime Item Development Specification for a typical weapon system trainer.

3.1 Prime Item Definition. The Combat Talon II Weapons System Trainer is intended for use in training qualified UPT graduates in all phases of the Combat Talon II mission at a schoolhouse. It shall comply with all requirements of this specification.

Example 2. Prime Item Development Specification for a mission rehearsal device.

3.1 Prime Item Definition. The Combat Talon I Mission Rehearsal Device is intended for use by qualified Combat Talon I aircrews to rehearse Special Forces missions with all appropriate players at the mission rehearsal facility. It shall comply with all requirements of this specification.

Example 3. System Specification for a limited fidelity device to be used at many sites.

3.1 System Definition. The F-15/F-16 Unit Training Device is intended for use by qualified pilots to practice air-to-air combat, air-to-ground weapon delivery, and emergency procedures at their regular training bases and operating sites. It shall comply with all requirements of this specification.

Example 4. System Specification for a specialized trainer.

3.1 Systems Definition. The Simulator for Electronic Combat Training is intended for use in training basic navigator students in electronic combat fundamentals at the Air Force Navigator Training Center. It shall comply with all requirements of this specification.

3.1.1 System Description. (SYSTEM). Not applicable.

4.2.1.1.1 Verification of System Description. (SYSTEM). Verification of this requirement is not applicable.

RATIONALE
This requirement is included only to match the outline of MIL-STD-490B. The performance required by the simulator, as well as its intended use, is covered in other paragraphs. It is recommended that this paragraph be "Not applicable."

3.1.2 Missions. (SYSTEM). Not Applicable.

4.2.1.1.2 Verification of Missions. (SYSTEM). Verification of this requirement is not applicable.

RATIONALE
This requirement is included only to match the outline of MIL-STD-490B. The performance required by the simulator, as well as its intended use, is covered in other paragraphs. It is recommended that this paragraph be "Not applicable."

3.1.3 Threat. (SYSTEM). Not applicable.

4.2.1.1.3 Verification of Threat. (SYSTEM). Verification of this requirement is not applicable.

RATIONALE
This requirement is included only to match the outline of MIL-STD-490B. There is no real "threat" for a simulator even though the simulator must frequently simulate a battlefield. Processes for obtaining data to do such a simulation must be covered in the Statement of Work, they should not be addressed as part of this paragraph or specification.

3.1.4 System Diagrams.
3.1.1 Prime Item Diagrams. __1__.

4.2.1.1.4 Verification of System Diagrams.
4.2.1.1.1 Verification of Prime Item Diagrams. Verification of this requirement is not applicable.

RATIONALE
Requirements Guidance:
1. Although diagrams are useful in expressing concepts, it is difficult to keep them consistent with specification text. The requirements must be fully and consistently captured. Generally the easiest (and recommended) approach is to put "Not applicable" into blank (1). Diagrams can then be provided in non-contractual explanatory material. If there is a compelling reason to use a diagram, blank (1) should introduce it appropriately.

EXAMPLES
Example 1. Recommended case.

3.1.4 System Diagrams. Not Applicable.

Example 2. Use of a diagram.

3.1.1 Prime Item Diagrams. Figure 1 is a diagram of the F-15 Unit Training Device.

3.1.5 Interfaces.
3.1.2 Interfaces. The simulator shall interface with the facility in which it is installed. __1__. __2__. Systems within the simulator shall interface as necessary to meet the requirements herein.

4.2.1.1.5 Verification of Interfaces.
4.2.1.1.2 Verification of Interfaces. This requirement shall be verified by (3) demonstration. Each required interface shall be (3) demonstrated. To the maximum extent possible, this (3) demonstration shall be conducted in conjunction with (4) other testing required by this specification.

RATIONALE
This will vary greatly from application to application. It is intended to be a top level set of requirements. There are many lower levels. When multiple contractors are involved and no contractor has full integration responsibility, it may be necessary for the government to get involved at the detailed signal level (as was done on the F-16 WST) -- but this should not be done here. Example (a) under Requirements Guidance (2) shows such a case; in this case the SOW should task interface specification development. In general, all of the examples shown in requirements guidance will require added SOW tasks, tailoring of additional specification paragraphs, or a combination of both. Safety-related interface requirements -- such as integration of the simulator fire detection system with that of the facility, or emergency lighting being integrated with the facility -- are to be included in paragraph 3.3.6 "Safety", NOT in this paragraph (in accordance with the concept of stating each requirement in one place only). Be aware that AFOSH Standards 127-22 and 127-118 include requirements that impact facility and facility interface; any specific facility interface feature should be consistent with these AFOSH Standards regardless of whether they are cited in paragraph 3.3.6 "Safety".

Requirements Guidance:

1. *Specify any special features of the facility interface. Some examples:*

   a. The facility shall supply power and air conditioning as necessary for simulator operation.

   b. The simulator hydraulic power supply heat exchangers shall be interfaced with the facility heat exchanger system.

2. *Specify any interfaces to other systems. Some examples:*

   a. The simulator shall interface with a separately procured visual system in accordance with Specification 202020 "Interface Specification for PQR Visual System".

   b. The simulator shall interface with the Distributed Interactive Simulation Network in accordance with IEEE Standard 1278-1993.

   c. The simulator shall interface with the A-10 and F-15 simulators on the same base in accordance with IEEE Standard 1278-1993.

   d. The simulator shall interface with up to three other FX simulators in the same facility.

   e. The simulator shall interface with the Training Management System (TMS) to provide information on student performance for evaluation and record keeping. The TMS shall automatically load the proper simulator mission script for the student's exercise.

   f. The simulator shall interface with the Training System Support Center (TSSC) in real time. It shall provide diagnostic information to the TSSC to support on-call maintenance activities.

g. The simulator shall interface with the Training System Support Center in real time such that environmental databases can be loaded upon command.

Verification Guidance:

3. Large complex interfaces, such as a separately procured visual system, should require a detailed interface test. Otherwise demonstration should suffice.

4. Delete the word "other" if verification by demonstration is required.

Process Guidance: *If facilities are built or modified, the SOW must provide for simulator manufacturer interface with the facility builder or modifier.*

3.1.3 Major Component List. (PIDS).

a. Synthetic Environment.
b. Cue Generators.
c. Simulated Air Vehicle.
d. Simulator control.
e. Simulation support.

4.2.1.1.3 Verification of Major Component List. (PIDS). Verification of this requirement is not applicable.

RATIONALE

In stating requirements the simulation device is not treated as a collection of subsystems (e.g., visual, radar, flight, tactics, etc.) as has been traditional. Instead, the specification takes a more natural (real-world) approach. The basic modes and states in which the simulator operates are defined up-front where they clearly apply to all major components. The major components are defined to include the synthetic environment and the simulated air vehicle. The synthetic environment corresponds closely to the world outside the air vehicle. Entities in the environment must be modeled to include properties applicable to all systems (e.g., visual, radar, IR); controls on the environment entities should affect all properties with one action. Similarly, the simulated air vehicle should correspond directly to the aircraft being simulated. A third major component, the cue generators, consist of simulator unique subsystems (image generators, motion system, etc.) that take the synthetic environment defined by various models, data bases, etc., and converts them to cues for the aircrew. A fourth major component includes all instructor controls, operator controls, displays, etc. The final major component, simulation support, describes the required capabilities to generate databases or other data required to support simulation exercises.

Requirements Guidance: *Item e may be deleted if not applicable.*

3.1.6 Government Furnished Material.
3.1.4 Government Furnished Material. __1__.

4.2.1.1.6 Verification of Government Furnished Material.
4.2.1.1.4 Verification of Government Furnished Material. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by inspection that ensures the material is available and used in the simulator.

RATIONALE
Use of government furnished material is generally avoided -- but it may be used depending on program requirements and constraints such as user requirements, availability, stability of design, and decisions on the use of aircraft hardware in the simulator. While government furnished material may save money, the government assumes some liability for the availability and quality of the material. Government liability may be minimized by statements that it be used "as available" (or "as is"), and "where available" (or "where is").

It is important to note the use of government furnished material is not the same issue as the use of aircraft hardware in the simulator, although the issues are closely related. When aircraft hardware is used it could be government furnished material, or it could be obtained from the aircraft contractor by the simulator manufacturer.

Requirements Guidance:
1. List any government furnished material or state "Not applicable", as appropriate.

Verification Guidance: *Select the alternative that matches the requirement.*

Process Guidance: *Where government furnished property is used, the acquisition of the property and its turn-over to the contractor must be managed. Certain contract clauses may also be appropriate.*

EXAMPLES
3.1.6 Government Furnished Material. The following items will be provided:

a. C-130H Control Columns (available as is).

b. Data base for 50000 square nautical miles centered at Little Rock, Arkansas, in Standard Interchange Format.

c. AIC-18 Interphone Control Panels.

3.1.5 Government Loaned Property. (PIDS). __1__.

4.2.1.1.5 Verification of Government Loaned Property. (PIDS). CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by inspection that ensures the property is available and used in the simulator.

RATIONALE
Government loaned property is rarely used in directly simulators.

Requirements Guidance:
1. List any government loaned property and the reason for the loan or state "Not applicable", as appropriate.

Verification Guidance: *Select the alternative that matches the requirement.*

Process Guidance: *Where government loaned property is used, the acquisition of the property and its turn-over to the contractor must be managed. Certain contract clauses may also be appropriate. Note also that when simulators are installed in government facilities, space must usually be provided for*

contractor logistics support. If the simulator is part of a training system, space for contractor instructors and space for academic instruction must also be provided. Requirements for such facilities and space are not appropriate in the specification, but should be covered by the Statement of Work or contract.

EXAMPLES
3.15 Government Loaned Material. The following items will be loaned for purposes of comparison during development and testing:

a. An aircraft mission computer.

b. Cockpit display system.

3.2 Characteristics.

4.2.1.2 Verification of Characteristics. Verification of this requirement is not applicable.

RATIONALE
This is an introductory, title-only paragraph.

3.2.1 Performance Characteristics. The simulator shall operate in the modes and simulation states as described in the following subparagraphs. The events and activities required shall occur in the modes required by the following subparagraphs.

4.2.1.2.1 Verification of Performance Characteristics. Verification of this requirement is not applicable.

RATIONALE
This is an introductory paragraph. Subparagraphs deal with many of the fundamental characteristics of the simulator. To discuss the fundamental characteristics it is necessary to define some terms. We begin by borrowing terms from control theory and slightly modifying their definition.

a. A state is the set of quantities X(t) which if they are known at t=t(0) are determined for t=>t(0) by specifying the inputs to the system for t=>t(0). [Kirk, Donald E., "Optimal Control Theory: An Introduction", Prentice Hall, Englewood Cliffs NJ, 1971] In more simple terms this represents the information that must be captured to compute the future behavior of the system. When used in this sense the word "state" should be modified by terms such as aircraft state, state of the aircraft, state of the enviroment, simulated engine state, simulator state, flyout state, etc.

b. State space, a term also borrowed from control theory, is the set of all possible states of simulator.

c. A simulation state is a subset of the state space which represents a useful description of the simulator condition from the viewpoint of a software designer. In most implementations a simulation state should mean that the executive software calls indentcal or similar subprograms. A simulation state is always preceeded by a state name, e.g. freeze state, replay state, normal mission state etc. When the term "simulation state" is used, the simulator is considered a finite state machine and each simulation state represents one of the states of that machine. The term "state" is often overloaded and used to mean simulation state. If this is done, it is important to avoid ambiguity in the context with which it is used.

d. A mode is a simulation state or collection of simulation states which represent fundamental ways of operating the simulator from the viewpoint of a crewmember or operator. Examples could include normal operating mode, networked operation, maintenance mode, part task operating modes, etc. Operation in a particular mode may result in operation in one or more simulation states. For example, the normal operating mode consists of the training state, the hard freeze state, the soft freeze state and the replay state.

e. An event signifies a change in the state of any system. Events are often initiated by commands from controls, as described in paragraph 3.7.4. Events may cause transitions between modes or simulation states, but they do not always do so.

f. An activity is a sequence of events ordered on time.

Modes and simulation states must be implemented consistently across all simulator subsystems. GET THE GRAPHICS BOOK FOR A TUTORIAL.

These requirements are typically identified by different agencies at different times during the simulator development process. Certain required modes like normal operating mode, networked operation, and part task operating modes would normally be identified by the government. The contractor would generally identify additional modes derived from other specification requirements such as maintainability or maintenance.

Once the modes are defined the contractor must define the simulation states. This definition must consider the modes as well as the required processes, events, and other simulation requirements such as motion safety, sickness prevention, the need to stabilize the simulation after control inputs, etc.

Individual states of the system fall out of the development process and are not defined by specification. The specification defines events and activities which result in certain required operating characteristics; there is a much larger set of activities which fallout of the simulator design.

3.2.1.1 Modes. The simulator shall operate in the modes required by the following subparagraphs.

4.2.1.2.1.1 Verification of Modes. Verification of this requirement is not applicable.

RATIONALE
This is a lead in paragraph only. The subparagraphs define the modes in which the simulator must operate. Modes may be categorized as follows:

a. Single-station Training Modes. In these modes the simulator operates as an entity all by itself. The entire aircraft and environment simulation is generated within the simulator. An entire aircrew (or portion thereof), and only one aircrew [or portion thereof] is trained on a single exercise at one time. Most major flight simulators can operate in this mode; e.g., the F-15, F-16, B-1, LANTIRN Part Task Trainer, etc.

b. Multi-station Training Modes. In these modes the simulator operates as an entity all by itself. All aircraft and environmental simulations are generated within the simulator. Multiple aircrews (or portions thereof) are trained on multiple simultaneous exercises. The Simulator for Electronic Combat Training operates in such a mode, as did the old T-37 and T-38 Simulators.

c. Interactive Modes. In these modes the simulator operates as simulator station on a communication network system connecting it to other simulator stations. The entire aircraft simulation is generated within the simulator for that aircraft. Each simulator shares the same synthetic environment with the other simulators on the network, and interacts in real time with these other simulators for group training. A simulator outputs its required position, dynamics, and environment-impacting activity information to update the shared synthetic environment across the network, and the simulator inputs the updates from other stations to keep its version of the shared environment current. The simulators on the network need not be identical, but must share adequate hardware and software commonality to provide a fully correlated depiction of the synthetic environment. The Distributed Interactive Simulation (DIS) standardization effort is an example of an attempt to define a number of

aspects of networked operation for simulators in the DoD community. Note that this mode should be used if the stations in a multi - station simulator operates interactively.

d. Partial Training Modes. In the case of simulators with a full mission training mode, there may be requirements to break the simulator into portions which can operate simultaneously and independently. The B-52 Weapons System Trainer is an example. There also may be partial training modes that require part of the system to operate while others undergo maintenance. For example, the remainder of the simulator operates fully while the visual system or radar simulation undergoes maintenance.

e. Maintenance modes to run diagnostics.

f. Other modes that may be applicable to a particular simulation problem.

Process Guidance: *Modes are fundamental operating characteristics of the devive. They should be defined in the initial version of the system specification or PIDS. Modes like a- d above would normally be identified by the government in their Systems Requirement Document for device procurements. The contractor should often identify additional modes derived from other requirements. These could include various maintenance modes.*

3.2.1.1.1 Single-station Training Mode (1). In the Single-station Training Mode (1), the simulated aircraft, synthetic environment, the cue generators, and the simulation control system shall meet all requirements of this specification.

4.2.1.2.1.1.1 Verification of Single-station Training Mode (1). This requirement shall be verified by test. Single-station Training Mode (1) operation shall be used for other testing required by this specification. Operation in this mode shall also be verified by operation of the simulator in exercises by aircrews such that all required capabilities are verified.

RATIONALE

This is the normal mode of operation for most simulators. It does not apply to simulators with multiple training stations (see Multi-station Training Mode).

Requirements Guidance

1. The title of this paragraph should be changed by the author to better reflect the operating characteristics or training requirements.

Verification Guidance

1. Rename the mode to be consistent with the requirement.

EXAMPLES

3.2.1.1.1 Normal Training Mode. In the Normal Training Mode, the simulated aircraft, synthetic environment, the cue generators, and the simulation control system shall meet all requirements of this specification.

3.2.1.1.2 Multi-station Training Mode [1]. In the Multi-station Training Mode (1), the simulated aircraft, synthetic environment, the cue generators and the simulation control system shall meet all requirements of this specification. All ___2____ trainee stations shall operate simultaneously on ______3_________. In addition any subset of the ___2___ trainee stations shall operate simultaneously, as required by this paragraph, while other trainee stations are shut down or undergoing maintenance. Except as otherwise stated in this specification all requirements apply simultaneously, and independently to the ____2_____ trainee stations.

4.2.1.2.1.1.2 Verification of Multi-station Training Mode [1]. This requirement shall be verified by test. Multi - station Training Mode (1) operation shall be used for other testing required by this specification. Operation in this mode shall also be verified by operation of the simulator in exercises by aircrews such that all required capabilities are verified.

RATIONALE

This mode will be the primary operating mode for multi- station simulators like the Simulator for Electronic Combat Training.

Requirements Guidance

1. The title of this paragraph should be changed by the author to better reflect the operating characteristics and training requirements.

2. Fill in the blank with the number of stations that must operate simultaneously.

3. This blank should be filled in as follows:

a. If the stations must operate only independently then use "on independent simulation exercises."

b. If the stations must operate only together then use "on a single integrated training exercise."

c. If both a and b apply then use "on independent simulation exercises or a single integrated training exercise."

Verification Guidance Rename the mode to be consistent with the requirement.

EXAMPLES

3.2.1.1.2 Four Student Training Mode. In the Four Student Training Mode, the simulated aircraft, synthetic environment, the cue generators and the simulation control system shall meet all requirements of this specification. All four trainee stations shall operate simultaneously on independent simulation exercises. In addition any subset of the four trainee stations shall operate simultaneously, as required by this paragraph, while other trainee stations are shut down or undergoing maintenance. Except as otherwise stated in this specification all requirements apply simultaneously, and independently to the four trainee stations.

3.2.1.1.3 Interactive Operation. In the interactive operation mode, the simulated aircraft, synthetic environment, cue generators and the simulation control system shall meet all requirements of this specification. Any subset of the simulator stations on the network shall operate simultaneously on a single integrated training exercise shall operate in a common and correlated synthetic environment within the specified latency requirements for the network. Upon command the simulator shall enter an integrated training exercise; it shall interact with the synthetic environment, and be part of the synthetic environment for other simulators in the exercise. [1]The command to enter an exercise shall operate at the beginning of an exercise as well as during an ongoing exercise. ___2___.

4.2.1.2.1.1.3 Verification of Interactive Operation. This requirement shall be verified by test. Interactive Operation shall be used for other testing required by this specification. Operation in this mode shall also be verified by operation of the simulator in exercises by aircrews such that all required capabilities are verified.

RATIONALE

Interactive Operation is a new area of concern in simulator design and there is little history or lessons learned available. It will usually be accomplished through a network, although other approaches are possible. This specification addresses the requirements and verifications for the development of simulators which can be part of a network and engaged in an interactive operation mode, but does not address the overall requirements of the network (e.g., network performance, required services, network security, and networked-simulation management). Two types of interactive operations are envisioned:

a. Interactive operation where all simulators which must interact are under the developer's control and are in the same local area; the contractor developing the interactive network should have maximum flexibility to design the inter - simulator operations.

b. Interactive operation where all simulators are not under the developer's control or are widely dispersed; a common system for defining inter - simulator operation must be used. Distributed Interactive Simulation (DIS) has been an on-going effort, by DOD, since 1989 to establish standards for the networking of dissimilar simulators. The process is not complete, it has not been tested for high performance simulators, and many problems are anticipated. It is however, likely to be accepted as a DOD or industry standard. It is the only known attempt to define inter - simulator operation.

DIS has produced draft Military Standard to define the requirements of communication architectures for DIS (CADIS) has been released, and an IEEE standard has been proposed to define the formats of the data packets (Protocol Data Units - PDUs) to be used for DIS. Full conformance to the DIS standards, published thus far, may not be the most cost effective approach for many programs, either in the short term or the long term. In general, the more requirements levied on a network system, the more it will cost. There currently exist several proven local area network (LAN) systems designed and under design specifically for the real-time industry, designed without regard to the proposed DIS protocols or services. The problem of providing real-time simulator interaction at a LAN site already has a number of solutions. The DIS is necessary on wide area networks (WAN) services for which the physical architecture and separation distances impose inherent difficulties to real-time interaction. However, the CADIS Military Standard defines both LANs and WANs together with little attempt to differentiate them. The requirements for LANs are similar to WANs, but not necessarily the same (for some examples, see the paragraph below). Hasty imposition of all DIS standards could result in a DIS requirements creep into LAN systems, unnecessarily raising the costs. If a non-DIS LAN is in place, an application gateway can interface the LAN to the wider DIS environment. An application gateway is a front-end dedicated processor which would handle DIS required services, including translating the LAN's data packets to DIS PDUs if necessary. Essentially, restrictions on LANs should be minimized. There can be value in the PDU standard of DIS which defines the types and units information useful for simulator interoperability. Nevertheless, there are still work-arounds for existing LANs which do not use PDU formats to interface with DIS through an application gateway. The trade- offs need to be considered carefully.

The following are some examples of specific network approaches which DIS would impose upon LANs by neglecting to differentiate between LAN and WAN requirements. There are often more cost and performance effective alternatives
for providing long-haul interoperability than forcing real-time LANs to satisfy DIS requirements (e.g., using application gateways to provide the required DIS services). One case in point is the DIS requirement for multicast/unicast service. A message is "broadcast" on a network when the message is sent to all stations on the network. A "multicast" (one-to-many) and "unicast" (one-to-one) service means a message can be sent to some selected subset of the stations on the network. Real-time LANs typically do not offer multicast/unicast services, simply because it's not needed, and the management overhead of destination and source addressing is eliminated. Broadcast on WANs may not be currently desirable, but imposing these restrictions on LANs is of questionable value if effective alternatives exist. Another example of potential DIS requirement creep into LAN design is the DIS requirement for dead reckoning computation to be done on each host and the requirements for dead reckoning information traffic on the network. Dead reckoning is a method of position and orientation estimation which the DIS standards provide to lessen the effects of latency and data corruption on networks. However, this is again not a real-time LAN problem, only a problem on WANs. Why impose the significant computational and network overhead on the LANs? A good answer and careful consideration of alternatives such as a single dedicated front end processor should be reached before imposing this cost on a simulator LAN site.

Requirements Guidance:

[1] This requirement assumes that it will be necessary to enter an interactive exercise at its beginning of or during an interactive exercise. If this is not the case the requirement must be appropriately tailored. Note that paragraph 3.2.1.2.4, Halt, requires removal of the simulator from the interactive exercise. With this requirement entry is necessary unless the simulator is not required to rejoin the exercise.

[2] The planned physical separation of the simulator stations within a site and the location of additional sites, if required, should be specified.

Process Guidance:

3.2.1.1.4 Partial Training Mode(s) [1]. The simulator shall operate in the following Partial Training (1) Modes

-OR-

In the Partial Training Mode (1) the simulator shall ________2____________.

4.2.1.2.1.1.4 Verification of Partial Training Mode(s) [1]. Verification of this requirement is not applicable

-OR-

This requirement shall be verified by test. A comprehensive test shall verify that all applicable requirements are met in the Partial Training Mode (1)

RATIONALE
There is an infinite set of possible partial training modes. They are highly individualized for particular programs and particular aircraft.

Requirements Guidance:

1. If no partial training modes are required this paragraph is not applicable. If there is more than one partial training mode is required do not change the title, use the first option and add subparagraphs describing each partial training mode. These subparagraphs should be similar to the information for blank

2. If only one partial training mode is required then the title should be changed to be more descriptive and the second option should be used.

2. Describe the partial training mode in terms of the operation of major components of this specification

Verification Guidance: *If more than one partial training mode is required use the first option and provide subparagraph similar to the second option to verify each required mode. If only one mode is required use the second option and rename the mode.*

Process Guidance:

3.2.1.1.5 Maintenance and Update Mode(s) [1]. The simulator shall operate in the following Maintenance and Update (1) Modes

-OR-

In the Maintenance and Update Mode (1) the simulator shall ___2__.

4.2.1.2.1.1.5 Verification of Maintenance and Update Mode(s) [1]. Verification of this requirement is not applicable

-OR-

This requirement shall be verified by test. A comprehensive test shall verify that all applicable requirements are met in the Maintenance and Update mode (1)

RATIONALE

This requirement is envisioned to be a contractor defined mode if necessary. It may be desirable to group maintenance and simulation support functions of the simulator as well as the into such a modes.

1. If no maintenance and update modes are required this paragraph is not applicable. If more than one maintenance or update mode is required do not change the title, use the first option and add subparagraphs describing each partial training mode. These subparagraphs should be similar to the information for blank 2. If only one partial training mode is required then the title should be changed to be more descriptive and the second option should be used.

2. Describe the partial training mode in terms of the operation of major components of this specification ***Requirements Guidance:***

Verification Guidance:

Process Guidance:

3.2.1.2 Events. Events shall occur as specified in the following subparagraphs.

4.2.1.2.1.2 Verification of Events. Verification of this requirement is not applicable.

RATIONALE

This is a lead in paragraph only.

3.2.1.2.1 Freeze. The freeze event shall occur in the __1__ mode(s) and cause all position updates to stop -- i.e., when freeze is commanded all entities shall remain in the same position and attitude where they were at the initiation of freeze. Mission time shall be stopped when freeze is initiated and its value held constant. All time derivatives (e.g., fuel flow, airspeed, rate of climb) shall be computed but shall not

be integrated. Simulated aircraft systems and controls shall operate normally (as required by this specification) except as precluded by the suspension of integration with respect to time. Entity signatures shall be generated during freeze. All simulation control required by this specification shall be operable except as precluded by suspension of mission time integration. Upon command, all integrations with respect to time shall resume.

4.2.1.2.1.2.1 Verification of Freeze. This requirement shall be verified by demonstration by commanding freeze as part of other verification activities.

RATIONALE
This paragraph establishes a standard definition for freeze. Freeze represents a non-physical situation so its properties are arbitrary. The freeze established by this definition is for training use. It allows a crewmember to observe a particular situation, and react to it appropriately. The basic concept is that relative positions remain fixed, radars continue to scan, controls operate normally, but no other events occur. Freeze is not intended to suspend a training exercise (see Halt). In interactive operation, it is recommended that freeze be a network-wide freeze, with the definition of freeze remaining the same. If the network protocol does not support freeze however, it is recommended that this requirement not apply to the interactive mode. If the network protocols contain other types of freezes (e.g., freeze of a single entity), then the simulator should also support these freezes.

Requirements Guidance: *In blank (1), include all mode names (e.g., single-station training mode, multi-station training mode, interactive mode, or partial training mode) applicable to this simulator.*

Process Guidance: *Since freeze is not representative of the physical world, it is very important that all implications of freeze, as defined in this paragraph, be reviewed, understood, and agreed to by the ultimate user. If further clarification of the freeze requirement is necessary, this paragraph should be modified accordingly.*

EXAMPLES
3.2.1.2.1 Freeze. The freeze event shall occur in the single-station training and partial training modes and cause all position updates to stop -- i.e., when freeze is commanded all entities shall remain in the same position and attitude where they were at the initiation of freeze. Mission time shall be stopped when freeze is initiated and its value held constant. All time derivatives (e.g., fuel flow, airspeed, rate of climb) shall be computed but shall not be integrated. Simulated aircraft systems and controls shall operate normally (as required by this specification) except as precluded by the suspension of integration with respect to time. Entity signatures shall be generated during freeze. All simulation control required by this specification shall be operable except as precluded by suspension of mission time integration. Upon command, all integrations with respect to time shall resume.

3.2.1.2.2 Malfunctions. Malfunction events shall occur upon command in the __1__ mode(s). A malfunction event shall be defined as a non-crewmember commanded change in the state of a simulated system used to represent a transient or permanent system component failure or degraded operation. The malfunctioned system and other systems shall respond to this change of system state in a natural manner in accordance with design criteria as limited by other requirements of this specification; i.e., the malfunction effects shall propagate through the simulated system in a manner analogous to failure propagation through the real system. Upon the command the malfunctioned system component shall return to its normal state. __2__.

4.2.1.2.1.2.2 Verification of Malfunctions. This requirement shall be verified by test. Each malfunction required by this specification shall be tested to ensure operation in accordance with design criteria and this specification by:

a. Commanding the malfunction

b. Observing the malfunction's effects

c. Observing the simulated system's response to crew procedures to overcome the malfunction's effects, if applicable, and

d. Observing a return to normal operation when a return to the normal state is commanded.

RATIONALE
This requirement defines malfunctions in a style consistent with the Structural Modeling approach to software design for real-time simulators. It requires natural propagation of malfunctions to the extent that a given system is simulated. Malfunction simulation often includes requirements to monitor and evaluate student responses to the simulated emergency conditions; such requirements should be included under the requirements for "Embedded Computer Based Training" elsewhere in this specification.

Requirements Guidance:

1. In blank (1), include all mode names (e.g., single-station training mode, multi-station training mode, interactive mode, or partial training mode) applicable to this simulator. If the required simulation fidelity is limited, it may be appropriate to change the second sentence to limit the effects of the malfunction using words such as, "Only the simulated aerodynamics and engines need respond to the change in simulated system state." For certain systems (such as the F-15 Weapons Tactics Trainer), no malfunctions are required; in this case, the entire paragraph should read, "This requirement is not applicable."

2. Blank (2) should identify the malfunctions to be simulated, or state "__(number)__ malfunctions shall be simulated as defined by the process required by the Statement of Work."

Process Guidance: *Complete definition of malfunctions has often proved to be difficult. If malfunctions cannot be identified up front, the Statement of Work must define a process to identify them. It is essential that the whole area of malfunctions be well understood and documented prior to any system test.*

EXAMPLES
Example 1. Malfunctions identified by Statement of Work process.

3.2.1.2.2 Malfunctions. Malfunction events shall occur upon command in the single-station training mode. A malfunction event shall be defined as a non-crewmember commanded change in the state of a simulated system used to represent a transient or permanent system component failure or degraded operation. The malfunctioned system and other systems shall respond to this change of system state in a natural manner in accordance with design criteria as limited by other requirements of this specification; i.e., the malfunction effects shall propagate through the simulated system in a manner analogous to failure propagation through the real system. Upon the command the malfunctioned system component shall return to its normal state. Two hundred fifty (250) malfunctions shall be simulated as defined by the process required by the Statement of Work.

Example 2. Malfunctions specifically identified.

3.2.1.2.2 Malfunctions. Malfunction events shall occur upon command in the multi-station training mode. A malfunction event shall be defined as a non-crewmember commanded change in the state of a simulated system used to represent a transient or permanent system component failure or degraded operation. The malfunctioned system and other systems shall respond to this change of system state in a natural manner in accordance with design criteria as limited by other requirements of this specification; i.e., the malfunction effects shall propagate through the simulated system in a manner analogous to failure propagation through the real system. Upon the command the malfunctioned system component shall return to its normal state. The following malfunctions shall be simulated:

a. Main fuel pump failure.

b. Flame out.

c. Compressor stagnation.

d. Tower shaft failure.

e. EEC failure

3.2.1.2.3 Crash. The crash event shall be commanded automatically when __1__.

The crash event shall cause the simulated aircraft and all entities to remain in the same state that they were in upon initiation of the crash event, except that all simulated power shall be removed from the simulated aircraft. Mission time shall be stopped and held constant upon initiation of the crash event. No cockpit controls shall function. The visual system and all other displays shall be blanked.

4.2.1.2.1.2.3 Verification of Crash. This requirement shall be verified by demonstration. (2)Each required crash condition shall be demonstrated.

RATIONALE
Requirements Guidance: *Blank (1) should be filled in with conditions that can cause crash. It is recommended that this be limited to, "the aircraft structural limits are exceeded."*

Past practice has been to specify a list of conditions that would result in crash, such as "a) ground contact in a non-takeoff or landing configuration, b) ground contact where the rate of descent exceeds aircraft structural limits, c) ground contact if the aircraft attitude is not within aircraft limits, d) ground contact outside the confines of a prepared surface, e) contact with a moving model, f) in-flight when the aircraft exceeds structural limits".

As modeling fidelity improves, it becomes increasingly difficult to handle cases in which physical laws are violated (as is often the case when crash is initiated upon satisfaction of one of a number of predefined conditions, such as listed above). For example, what should the model produce if the physical laws indicate that aircraft structural limits are exceeded, but none of the specifically listed conditions is encountered? It is recommended that the crash event be dictated by physical laws, so that mathematical artifices are not required. For example, if an aircraft catches a wing tip on landing (which would initiate an immediate crash event under the past practice of listing predefined crash conditions), allow the simulation to continue until structural limits are actually exceeded; this has an additional benefit in that the cause of the crash is immediately obvious to both student and instructor.

Verification Guidance: *Delete the sentence following (2) unless a list of predefined crash conditions is included.*

EXAMPLES
3.2.1.2.3 Crash. The crash event shall be commanded automatically when the aircraft structural limits are exceeded.

The crash event shall cause the simulated aircraft and all entities to remain in the same state that they were in upon initiation of the crash event, except that all simulated power shall be removed from the simulated aircraft. Mission time shall be stopped and held constant upon initiation of the crash event. No cockpit controls shall function. The visual system and all other displays shall be blanked.

4.2.1.2.1.2.3 Verification of Crash. This requirement shall be verified by demonstration.

3.2.1.2.4 Halt. The halt event shall occur in the __1__ mode(s). When halt is commanded, this event shall suspend all changes to the simulator state and allow safe exit from (the/all) crew station(s). Upon

command, the simulator shall be restored to its state at the initiation of the original halt command and the simulation exercise shall continue from that point unless another event or activity has been commanded during the halt interval. (2)In interactive mode, the halt event shall remove the simulator from the interactive exercise.

4.2.1.2.1.2.4 Verification of Halt. This requirement shall be verified by demonstration. Halt shall be commanded, and subsequently the exercise shall be resumed.

RATIONALE
This event is similar to some definitions used for freeze; however, it is not intended for training purposes, but instead handles other interruptions to a simulator exercise such as maintenance or emergency situations (see Freeze). In interactive operation, the halt event should remove the simulator from the interactive exercise.

Requirements Guidance:

1. In blank (1), include all mode names (e.g., single-station training mode, multi-station training mode, interactive mode, or partial training mode) applicable to this simulator.

2. If interactive modes are not included in blank (1), delete the sentence following (2).

EXAMPLES
3.2.1.2.4 Halt. The halt event shall occur in the four-station training mode. When halt is commanded, this event shall suspend all changes to the simulator state and allow safe exit from all crew stations. Upon command, the simulator shall be restored to its state at the initiation of the original halt command and the simulation exercise shall continue from that point unless another event or activity has been commanded during the halt interval.

3.2.1.3 Activities. The following activities shall occur in the simulator.

4.2.1.2.1.3 Verification of Activities. Verification of this requirement is not applicable.

RATIONALE
This is a lead in paragraph only.

3.2.1.3.1 Record. This activity shall occur in the ___1___ mode(s) and shall include recording of ___2___. Recording shall suspend when mission time is not updating.

a. (3) A snapshot is any simulator state from which the crew can begin flying and successfully control the simulated aircraft with the state of the synthetic environment unchanged from the instant of the snapshot. Up to ___4___ snapshots shall be recorded ___5___.

b. (6) A mission segment recording shall capture all data necessary to fully replay ___7___.

c. (8) Within a mission segment recording ____9___ snapshots shall be recorded ___10___ .

4.2.1.2.1.3.1 Verification of Record. This requirement shall be verified by test. Simulation exercise using all systems and features required by this specification to their maximum extent shall be recorded to provide ___11___ which shall successfully meet replay requirements.

RATIONALE
Record is used for different purposes:

a. To capture the simulator state at a given point in time so that the simulator can be returned to that point and an exercise can be flown by the crew in a normal manner from that point. The simulator state at the given point in time is defined as a snapshot.

b. To capture a subset of simulator states over a portion of the training exercise so that the mission can be replayed to critique the trainee. Such a portion of the training exercise is defined as a mission segment

c. To capture a subset of simulator states over a portions of various training exercise flown by expert crew members so that the desired trainee can be illustrated on multiple missions. (Multiple Mission Segments)

d. Combinations of the above.

There are serious technical implications with each of the different purposes. With a. the complete aircraft state must be captured. This is especially difficult if aircraft processors are used in the simulation although solutions have been developed for this problem. With b. while the complete state data could be captured at rapid intervals and stored; it is often more practical and simple to merely capture and store the key signals driving instruments, displays etc. Recording of data uses a great deal of disc space although storing drive signals will often use less. With a. this storage grows in direct proportion to the number of snapshots. With b it grows in proportion to the length of the recorded mission segments. In addition, with c it grows in proportion to both the length of the mission segments and the number that must be recorded. This requirement should not be levied casually. The user should have a definite need for it and a serious plan to use it. If recording is not required the paragraph is not applicable. If it is required the number of snapshots, the length of the mission segments, and the number of segments must be defined. If flyout points are required continuously throughout each mission segment then any saving from recording drive signals is lost. In interactive operation recording at a single station should capture the total network performance as seen by that station.

Requirements Guidance:

1. The blank should be filled in with the applicable modes. In general this requirement should apply in the single station training mode, multi - station training modes, and interactive modes.

2. Fill in the blank with one of the following: snapshots; mission segments; snapshots and mission segments; flyout states within mission segments; flyout states and flyout states within mission segments; mission segments and flyout states within mission segments; flyout states, mission segments, and flyout states within mission segments.

3. Delete this requirement if recording of flyout states is not required. If only flyout states within mission segments must be recorded delete the second sentence.

4. Specify the number of flyout states that must be recorded if this recording is required upon command. If there is only continuous recording over a time interval the words "Up to" and the blank should be deleted.

5. Specify how recording is initiated. Options include:

a. "upon command"

b. "for a ___(number)___ minute period at ___(number)___ second intervals when commanded.

c. "for the last ___(number)___ minute period at ___(number)___ second intervals.

d. a and b above

e. a and c above

6. Delete this item if recording of mission segments is not required.

7. Specify the length of the segment and the method of initiating the recording. Options include:

a. Any commanded portion of the last ___(number)___ minutes of the training exercise.

b. Any commanded portion of a commanded ___(number)___ minute segment of the training exercise.

10 - 20 minutes are typical values for recording time.

8. Delete this paragraph if recording of flyout points within mission segments is not required.

9. Specify the number of snapshots that must be recorded during a mission segment only if this recording is required upon command. If there is only continuous recording over a time interval the blank should be deleted.

10. Specify how recording of snapshots within a recorded mission segment is initiated. Options include:

a. "upon command"

b. "At ____ (number) _____ second intervals throughout the entire segment".

c. a and b above.

Verification Guidance: *Fill in blank 11 with "snapshots", "snapshots and mission segments", or "mission segments" as appropriate.*

Process Guidance:

EXAMPLES
NOTE: Three examples consisting of both requirements and verification paragraphs are provided; each example parallels the corresponding example in the Replay paragraph.

Example 1. Commanded recording of flyout states and mission segments. Flyout states continuously recorded within mission segments.

3.2.1.2.2 Record. This activity shall occur in the normal training and partial training modes and shall include recording of flyout states, mission segments, and flyout states within mission segments. Recording shall suspend when mission time is not updating.

a. A flyout state is any simulator state from which the crew can begin flying and successfully control the simulated aircraft. Up to 10 flyout states shall be recorded upon command.

b. A mission segment recording shall capture all data necessary to fully replay any commanded portion of a commanded 15 minute segment of the training exercise.

c. Within a mission segment recording flyout states shall be recorded at 15 second intervals throughout the entire segment.

4.2.1.2.1.3.1 Verification of Record. This requirement shall be verified by test. Simulation exercise using all systems and features required by this specification to their maximum extent shall be recorded to provide flyout states and mission segments and which successfully meet replay requirements.

Example 2. Flyout states recorded in an interval upon command.

3.2.1.2.2 Record. This activity shall occur in the multi - station training mode and shall include recording of flyout states. A flyout state is any simulator state from which the crew can begin flying and successfully control the simulated aircraft. Flyout states shall be recorded for a 15 minute period at 60 second intervals when commanded. Recording shall suspend when mission time is not updating.

4.2.1.2.1.3.1 Verification of Record. This requirement shall be verified by test. Simulation exercise using all systems and features required by this specification to their maximum extent shall be recorded to provide flyout states which shall successfully meet replay requirements.

Example 3 Continuous Mission segment recording; flyout states recorded upon command

3.2.1.2.2 Record. This activity shall occur in the integrated training mode and shall include recording of mission segments and flyout states within mission segments. A flyout state is any simulator state from which the crew can begin flying and successfully control the simulated aircraft. A mission segment recording shall capture all data necessary to fully replay any commanded portion of the last 10 minutes of the training exercise. Within a mission segment recording up to five flyout states shall be recorded upon command.

4.2.1.2.1.3.1 Verification of Record. This requirement shall be verified by test. Simulation exercise using all systems and features required by this specification to their maximum extent shall be recorded to provide flyout states and mission segments which shall successfully meet replay requirements.

3.2.1.3.2 Replay. The replay activity shall:

a. (1) Set the simulator to ___2___ flyout state. The state of the simulator shall remain constant until a release is commanded. Upon release the simulator shall operate in accordance with the requirements of this specification.

b. (3) Set the simulator to the start of ___4___ mission segment(s) or any commanded point in the mission segment(s). The state of the simulator shall remain constant until a release is commanded. Upon release all simulator displays shall exactly repeat their total performance on the mission segment. When commanded the replay shall stop and the state of the simulator shall remain constant. At the conclusion of the mission segment the state of the simulator shall remain constant.

(5)The following controls shall be shall be ___6___:
___7___.

(8) Information on all (9) other controls shall be provided so that the crew member can set them to the proper position prior to release.

-OR-

The position of all (9) other controls need not change during replay.

-OR-

Information on the following controls shall be provided so that the crew member can set them to the proper position prior to release:

___10___.

The position of all other controls need not change during replay.

4.2.1.2.1.3.2 Verification of Replay. This requirement shall be verified by analysis and test. ___11___ flyout states shall be recorded. The simulator shall be released and a short segment flown by the crew. ___12___ mission segments shall be recorded. Replays shall be commanded and verified. During the replays the requirements to start at various points and to stop shall be verified. The system's maximum capability for storing and recalling replay data shall be determined by analyzing computer resource data.

RATIONALE

This requirement is dependent on the record requirement and they must match; i.e. if only snapshots are recorded then only the portion of replay that is applicable is setting the simulator to a flyout state. The replay also involves

Requirements Guidance:

1. *Delete this paragraph if recording of snapshots is not required.*

2. *This blank defines the number of snapshots that must be stored and be available for use. If only one flyout state is required state use "the" in this blank. If more than one is required fill in the blank with "any commanded recorded flyout state".*

3. *Delete this paragraph if recording of mission segments is not required.*

4. *This blank defines the number of mission segments that must be stored and be available for use. If only one mission segment is required state use "the" in this blank. If more than one is required fill in the blank with "any of __(number)__ commanded".*

5. *Delete this paragraph if no automatic setting of controls to their proper position at the snapshots or the start of a mission segment replay is required and no movement of controls during replay of mission segments is required.*

6. *This blank defines the automatic control movement required. The options include:*

   a. *"automatically driven to their correct position at the flyout state"*

   b. *"automatically driven to their correct position at the start of the mission segment being replayed and to their correct position throughout the mission segment being replayed".*

   c. *"automatically driven to their correct position at the flyout state and the start of and throughout the mission segment being replayed".*

7. *List the controls that must move automatically; the usual candidates are the flight controls and the throttle. This must be correlated with the requirements of paragraphs 3.7.3.6.1.1, 3.7.3.6.1.2 etc. to automatically position the controls. If the controls are not driven automatically this requirement is not possible.*

8. *Select one of the paragraph options. Ignoring control positions will provide less interruption to training exercise.*

9. Delete "other" if no controls must move automatically.

10. List controls

Verification Guidance:

11. Select the number of snapshots to be recorded and verified. Three should generally be sufficient. If recording of snapshots is not required delete the entire sentence.

12. Select the number of mission segments to be recorded and verified. Three should generally be sufficient. If recording of snapshots is not required delete this sentence as well as the next two sentences.

Three examples consisting of both requirements and verification paragraphs are provided; each example parallels the corresponding example in the Record paragraph.

Process Guidance:

EXAMPLES
NOTE: Three examples consisting of both requirements and verification paragraphs are provided; each example parallels the corresponding example in the Record paragraph.

Example 1. Replay of flyout states and mission segments. Various control requirements for controls

3.2.1.3.2 Replay The replay activity shall:

a. Set the simulator to any commanded recorded flyout state. The state of the simulator shall remain constant until a release is commanded. Upon release the simulator shall operate in accordance with the requirements of this specification.

b. Set the simulator to the start of any of 10 mission segments or any commanded point in the mission segments. The state of the simulator shall remain constant until a release is commanded. Upon release all simulator displays shall exactly repeat their total performance on the mission segment. When commanded the replay shall stop and the state of the simulator shall remain constant. At the conclusion of the mission segment the state of the simulator shall remain constant.

The following controls shall be automatically driven to their correct position at the start of the mission segment being replayed and to their correct position throughout the mission segment being replayed:

a. Control stick

b. Throttles

c. Rudder pedals

Information on the following controls shall be provided so that the crew member can set them to the proper position prior to release:

a. HF radio.

b. UHF radio

c. VHF radio

The position of all other controls need not change during replay.

4.2.1.2.1.3.2 Verification of Replay. This requirement shall be verified by analysis and test. Three flyout states shall be recorded. The simulator shall be released and a short segment flown by the crew. Three mission segments shall be recorded. Replays shall be commanded and verified. During the replays the requirements to start at various points and to stop shall be verified. The system's maximum capability for storing and recalling replay data shall be determined by analyzing computer resource data.

Example 2. Replay of flyout states; crew member sets all controls

3.2.1.3.2 Replay. The replay activity shall set the simulator to any commanded recorded flyout state. The state of the simulator shall remain constant until a release is commanded. Upon release the simulator shall operate in accordance with the requirements of this specification. Information on all controls shall be provided so that the crew member can set them to the proper position prior to release.

4.2.1.2.1.3.2 Verification of Replay. This requirement shall be verified by analysis and test. Three flyout states shall be recorded. The system's maximum capability for storing and recalling replay data shall be determined by analyzing computer resource data.

Example 3. Replay of flyout states and mission segments; controls do not change in replay.

3.2.1.3.2 Replay. The replay activity shall:

a. Set the simulator to any commanded recorded flyout state. The state of the simulator shall remain constant until a release is commanded. Upon release the simulator shall operate in accordance with the requirements of this specification.

b. Set the simulator to the start of any of 12 commanded mission segments or any commanded point in the mission segments. The state of the simulator shall remain constant until a release is commanded. Upon release all simulator displays shall exactly repeat their total performance on the mission segment. When commanded the replay shall stop and the state of the simulator shall remain constant. At the conclusion of the mission segment the state of the simulator shall remain constant. The position of all other controls need not change during replay.

4.2.1.2.1.3.2 Verification of Replay. This requirement shall be verified by analysis and test. Three flyout states shall be recorded. The simulator shall be released and a short segment flown by the crew. Three mission segments shall be recorded. Replays shall be commanded and verified. During the replays the requirements to start at various points and to stop shall be verified. The system's maximum capability for storing and recalling replay data shall be determined by analyzing computer resource data.

3.2.1.3.3 Stabilization. The simulator shall be stable after any event or activity required by this specification except for commanded introduction of malfunctions which produce unstable conditions. All controls shall be trimmed such that the simulated aircraft is flyable. ___(1)___ shall automatically move to the trimmed condition. Information on the following controls shall be provided so that the crew member can set them to the trimmed position prior to release: ___2___. Where possible, changes to the simulator's state shall, be introduced gradually so as to not make the simulated aircraft uncontrollable or to introduce divergent conditions into the aircraft or environment simulations. If this is not possible, the simulation exercise shall be suspended, all required changes to the state of the simulator shall occur, and the new states shall be held constant until a release is commanded. The maximum allowable time for required for this activity shall not exceed ___3___.

4.2.1.2.1.3.3 Verification of Stabilization. This requirement shall be verified by demonstration in conjunction with tests required by this specification.

RATIONALE

Transition between states is often a non - real world, non - physical simulator activity that is very useful in many training activities. It can however cause great divergence in simulator systems.

Requirements Guidance:

1. *List the controls that must move automatically; the usual candidates are the flight controls and the throttle. This must be correlated with the requirements of paragraphs 3.7.3.6.1.1, 3.7.3.6.1.2 etc. to automatically position the controls. If the controls are not driven automatically this requirement is not possible.*

2. *List controls for which information must be provided.*

3. *Specify the maximum time for mode changes and any qualifying conditions. The shortest possible time is desirable but in training exercises of an hour more with complex environment five minutes may be a practical value.*

Process Guidance:

EXAMPLES

3.2.1.3.3 Stabilization. The simulator shall be stable after any event or activity required by this specification except for commanded introduction of malfunctions which produce unstable conditions. All controls shall be trimmed such that the simulated aircraft is flyable. The control column and throttles shall automatically move to the trimmed condition. Information on the following controls shall be provided so that the crew member can set them to the trimmed position prior to release: flap handles and landing gear control. Where possible, changes to the simulator's state shall, be introduced gradually so as to not make the simulated aircraft uncontrollable or to introduce divergent conditions into the aircraft or environment simulations. If this is not possible, the simulation exercise shall be suspended, all required changes to the state of the simulator shall occur, and the new states shall be held constant until a release is commanded. The maximum allowable time for required for this activity shall not exceed five minutes.

3.2.1.3.4 Crash Override. The crash override activity shall occur in the __1__ mode[s]. If crash override is commanded when a crash has occurred, the crash override activity shall restore the simulator to a stable state approximating the simulator's state prior to the crash [2] and shall prevent the crash from occurring again. If commanded when no crash has occurred, the crash override activity shall prevent any crash condition from occurring. When disable crash override is commanded crashes shall occur as required by this specification.

4.2.1.2.1.3.4 Verification of Crash Override. This requirement shall be verified by demonstration. Crash override shall be specifically demonstrated during other testing required by this specification.

RATIONALE
Crash override is a common feature in simulators. It has two functions:

a. To quickly restore a simulator to normal conditions after a crash.

b. To prevent crashes from occurring.

The second feature has limited training value and could reinforce inappropriate behaviors. It also requires the introduction of mathematical artifices to handle the modeling of situations that have no basis in physical reality (e.g., What are the assumptions to be made for modeling the aircraft's flight underground? How are boundary conditions to be handled as the aircraft re-emerges from the ground?). The enabling or disabling of this feature is accomplished by one of one of the simulation control features of paragraph 3.7.4.1.

Requirements Guidance:

1. The blank should be filled in with the applicable modes. In general this requirement should apply in the single-station training mode, multi-station training modes, and interactive modes.

2. The remainder of the paragraph should be deleted if only a restore capability is required. Due to the problems associated with this feature's inclusion and its lack of utility, it is recommended that only the restore capability be included.

EXAMPLES
The crash override activity shall occur in the multi-station operating mode. If crash override is commanded when a crash has occurred, the crash override activity shall restore the simulator to a stable state approximating the simulator's state prior to the crash.

3.2.1.3.5 Set and Reset of Expendables. This activity shall occur in the ___1___ mode[s]. When commanded the following simulated expendable quantities associated with the simulated air vehicle shall be set to the commanded values:
___2___

4.2.1.2.1.3.5 Verification of Set and Reset of Expendables. This requirement shall be verified by test. Each required expendable quantity shall be commanded to its full range of conditions as required by this specification.

RATIONALE
This paragraph provides the capability for commanding change the state of the simulated vehicle. It implies a capability to set these values at the start of the exercise and to reset them at appropriate points in an exercise.

Requirements Guidance: *Fill in the blanks as follows:*

1. This blank should be filled in with the applicable modes. In general this requirement should apply in the single station training mode, multi - station training modes and interactive mode.

2. Typical vehicle characteristics that can be changed could include fuel load, expendables load, weapon load, weapon configuration, cargo load, etc. The blank should be filled in with the items required.

Process Guidance:

EXAMPLES
3.2.1.3.5 Set and Reset of Expendables. This activity shall occur in the single station training mode. When commanded the following simulated expendable quantities associated with the simulated air vehicle shall be set to the commanded values:

a. Fuel to any load consistent with design criteria.

b. Weapons to any configuration required by this specification or to any other configurations which would result from a launch of one or more weapons from these original configurations.

c. Any chaff and flare load consistent with design criteria.

d. Gun ammunition to any load consistent with design criteria.

3.2.1.3.6 Set and Reset of Environmental Conditions. This activity shall occur in the ___1___ modes. When commanded the following characteristics of the synthetic environment shall be set to the commanded values:
___2___

4.2.1.2.1.3.6 Verification of Set and Reset of Environmental Conditions. This requirement shall be verified by test. Each required environmental characteristic shall be commanded to its full range of conditions as required by this specification.

RATIONALE
This paragraph provides the capability for commanding change the state of the synthetic environment. It implies a capability to set the values at the start of the exercise and to reset them at appropriate points in an exercise. This capability is basic in that it does not correlate the environmental conditions with each other or the simulated vehicle. Such correlation can be accomplished by simulator mission scripts [see 3.7.4] or

Requirements Guidance: *Fill in the blanks as follows:*

1. This blank should be filled in with the applicable modes. In general this requirement should apply in the single station training mode, multi - station training modes, and interactive training modes.

2. Typical environment characteristics that could be changed include meteorological characteristics such as temperature and wind, meta-model characteristics such as positions, velocities and frequencies, time of day, etc. The second blank should be filled in with these items as required.

Process Guidance:

EXAMPLES
3.2.1.3.6 Set and Reset of Environmental Conditions. This activity shall occur in the single station training mode. When commanded the following the following characteristics of the synthetic environment shall be set to the commanded values:

a. The positions, weapons load, fuel loads, of all simulated vehicles in the environment as required by this specification.

b. The surface winds and temperature at any simulated airfield.

3.2.1.3.7 Set and Reset of Simulated Aircraft Position. This activity shall occur in the ___1___ mode(s). When commanded the simulated aircraft shall be set to any commanded ___2___ position and attitude consistent with the other requirements of this specification. The position of the aircraft shall not update until commanded. The aircraft shall be initialized in a stable position such that normal operations can be trained upon command. Mission time shall ___3___.

4.2.1.2.1.3.7 Verification of Set and Reset of Simulated Aircraft Position. This requirement shall be verified by test. The simulation shall be set or to ___4___ different positions and attitudes throughout the required performance envelope.

RATIONALE
Requirements Guidance:

1. Fill in this blank with the applicable mode names; in general this requirement should apply in the single station training mode, multi - station training modes....?

2. This blank should specify whether the requirement applies to in-flight states, ground states, or both.

3. This blank should state how mission time is handled in the set or reset; some options are "shall remain fixed at the time the activity is initiated", "shall be set to zero", or "shall be set to the commanded value".

Verification Guidance:

4. Fill in the number of positions to be tested. Three should generally be sufficient.

Process Guidance:

EXAMPLES
3.2.1.2.7 Set and Reset of Simulated Aircraft Position. This activity shall occur in the multi - station training mode. When commanded the simulated aircraft shall be set to any commanded in-flight state or ground position and attitude consistent with the other requirements of this specification. The position of the aircraft shall not update until commanded. The aircraft shall be initialized in a stable position such that normal operations can be trained upon command. Mission time shall be set to zero.

4.2.1.2.1.3.7 Verification of Set and Reset of Simulated Aircraft Position. This requirement shall be verified by test. The simulation shall be set or to three different positions and attitudes throughout the required performance envelope.

3.2.1.3.8 Mission Time Management. The simulator shall manage mission time in the __1__ mode(s). Upon command mission time shall be set to zero or other commanded value. It shall then increase in

real time throughout the training exercise, except where otherwise required by this specification. All time references, except those controlling entity activity and sensor scanning in the simulated aircraft, shall relate directly to mission time (i.e., when mission time is increasing these referenced times shall increase, and when mission time is not increasing these referenced times shall not increase). (2) In the interactive mode, mission time shall be common to all simulators on the network.

4.2.1.2.1.3.8 Verification of Mission Time Management. This requirement shall be verified by demonstration.

RATIONALE
Mission time represents the elapsed time from the start of a simulator mission to the current point in the mission -- if there have been no freezes, halts, etc. It is the same interval of time that would occur if the mission were flown in an aircraft. Mission time has usually been available in simulators; this paragraph creates an explicit requirement. It is intended that mission time will be available for scripting (see paragraph 3.7.4). This requirement also ties all delays in the simulation (such as the time for a piece of simulated equipment to warm up) directly to mission time. This will suspend such delays while the simulator is in freeze, etc. It is intended that the on-board radars and other sensors continue to scan when mission time is not increasing. It is also intended that the signature of objects in the environment (entities) be generated in a dynamic manner even though mission time is not increasing.

Requirements Guidance

1. *Fill in blank (1) with the applicable mode names. In general, this requirement should apply in the single-station training mode, multi-station training modes, and in interactive modes.*

2. *Delete the sentence following (2) if an interactive mode is not required.*

EXAMPLES
3.2.1.3.8 Mission Time Management. The simulator shall manage mission time in the single-station training and partial training modes, as well as during interactive mode operation. Upon command mission time shall be set to zero or other commanded value. It shall then increase in real time throughout the training exercise, except where otherwise required by this specification. All time references, except those controlling entity activity and sensor scanning in the simulated aircraft, shall relate directly to mission time (i.e., when mission time is increasing these referenced times shall increase, and when mission time is not increasing these referenced times shall not increase). In the interactive mode, mission time shall be common to all simulators on the network.

3.2.1.4 Simulation States. The simulator shall operate in simulation states as required by the following subparagraphs.

4.2.1.2.1.4 Verification of Simulation States. This requirement shall be verified by test which ensures that the simulator can enter and exit each state as well as that the operation of each state meets the requirements of this specification.

RATIONALE
The definition of simulation states is critical to achieve a consistent software design. The definition should be based on the required modes, events, and activities. It is also essential that all parties involved in the acquisition understand the fundamental operation of the simulator.

Requirements Guidance: *A subparagraph should be provided with a description of each simulation state*

Verification Guidance: *Provide a verification subparagraph for each requirements paragraph.*

Process Guidance: *If the program requires both a system specification and a PIDS then this paragraph is not appropriate for the system specification. If only specification is required then the paragraph should be included only in that specification. It is recommended that the contractor developing the system write this paragraph after a full analysis of the simulation. In some cases this may be done with the proposal but in other cases, especially if the contractor is not familiar with structural modeling more time will be required. In this case the Statement of Work should require that simulation states be defined and this paragraph be updated prior to?*

EXAMPLES
3.2.1.4 Simulation States. The simulator shall operate in simulation states as required by the following subparagraphs.

3.2.1.4.1 Initialization State. This simulation state shall set all the necessary data such that the simulator can operate in the Single Station Training Mode. It shall place the simulated aircraft at the commanded position and set up the environment to respond as required by this specification. It shall initialize all cue generators and simulation control. During initialization the visual display shall be blanked and the motion system shall move smoothly to the neutral position. At the completion of initialization the simulator shall automatically transfer to the soft freeze state with mission time fixed at zero.

3.2.1.4.2 Normal Training State. This simulation state shall provide all fully dynamic training (i.e. the simulated aircraft and all mobile meta models update as required herein) in the Single Station Training Mode. Appropriate visual and sensor displays are available. Record activity shall be available upon command Mission time shall increase continuously. All motion cues shall be available.

3.2.1.4.3 Soft Freeze State. This simulation state shall implement the requirements of paragraph. In addition the motion system shall settle smoothly and slowly to a neutral position.

3.2.1.4.4 Hard Freeze State. This simulation state shall implement the requirements of paragraph. In addition the visual system and all other displays shall be blanked. The motion system shall settle smoothly to a neutral position.

3.2.1.4.5 Replay State. This simulation state shall implement the requirements of paragraph 3.2.1.3.2. for replay of mission segments.

3.2.1.4.6 Stabilization State 1. This paragraph shall implement the requirements of paragraph 3.2.1.3.3 when changes to simulator states do not necessitate a total suspension of the simulation. The simulator shall automatically enter this state when necessary and leave it automatically when stabilization is complete. The simulator shall function normally (in accordance with this specification) except as necessary to perform the stabilization.

3.2.1.4.7 Stabilization State 2. This paragraph shall implement the requirements of paragraph 3.2.1.3.3 when changes to simulator states necessitate a total suspension of the simulation. The visual system and all other displays shall be blanked. The motion system shall move smoothly and gradually as necessary to accomplish the changes.

3.2.1.4.8 Maintenance State. This simulation state shall implement a series of diagnostics which isolate 95% of all faults in the image generator, computational system, and simulator I/O system to the single circuit card with a 5% probability of false alarm. Entry into this state shall be controlled with a password protection scheme.

4.2.1.2.1.4 Verification of Simulation States. This requirement shall be verified by test which ensures that the simulator can enter and exit each state as well as that the operation of each state meets the requirements of this specification.

4.2.1.2.1.4.1 Verification of Initialization State. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

4.2.1.2.1.4.2 Verification of Normal Training State. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

4.2.1.2.1.4.3 Verification of Soft Freeze State. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

4.2.1.2.1.4.4 Verification of Hard Freeze State. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

4.2.1.2.1.4.5 Verification of Replay State. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

4.2.1.2.1.4.6 Verification of Stabilization State 1. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

4.2.1.2.1.4.7 Verification of Stabilization State 2. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

4.2.1.2.1.4.8 Verification of Maintenance State. This requirement shall be verified by test in accordance with paragraph 4.2.1.2.1.4.

3.2.1.5 Simulator Dynamic Response. Throughput latency and cue synchronization of the (1) physical motion, visual, and cockpit instrument cue (hereafter referred to as the primary cues) responses to a control input at the pilot station shall be as specified in 3.2.1.5.1 and 3.2.1.5.2. This requirement shall be satisfied with the attenuation and lag effects of the aerodynamic forces and moments bypassed, but with the time lags associated with all computations retained.

4.2.1.2.1.5 Verification of Simulator Dynamic Response. CHOOSE ONE OF THE FOLLOWING THREE ALTERNATIVES:

This requirement shall be verified by test. Throughput latency and cue synchronization of the primary cue drives shall be verified by test in accordance with the procedures of the "Airplane Flight Simulator Evaluation Handbook" as follows: (2)

Section 4a Simulator Pitch Response
Section 4a Simulator Roll Response
Section 4a Simulator Yaw Response

In the event of a conflict, the requirement as specified herein takes precedence over the "Airplane Flight Simulator Evaluation Handbook".

-OR-

This requirement shall be verified by test. Throughput latency and cue synchronization of the primary cue drives shall be verified by test in accordance with Appendix 2 of the AC-120-63 "Helicopter Simulator Qualification" as follows: (2)

Test 5a Visual, motion, and cockpit instrument response

In the event of a conflict, the requirement as specified herein takes precedence over Appendix 2 of the AC-120-63 "Helicopter Simulator Qualification".

-OR-

This requirement shall be verified by test. Throughput latency and cue synchronization of the primary cue drives shall be verified by test in accordance with the following procedure.

Time histories of the following input signal and primary cue responses shall be recorded simultaneously: (3)

a. Control (4) deflection/force signal.
b. Primary cockpit indication of aircraft attitude.
c. Motion cuing device acceleration or equivalent signal.
d. Visual position cue at the display system output.

(5)Lags associated with visual image presentation shall be defined to be one-half of the imagery update period, where the imagery update period is the inverse of the image update rate.

The software shall be configured such that the normal calculations of aerodynamic forces and moments are bypassed, and the injected test signal is substituted in their stead. Otherwise, all software shall be configured for normal, operational execution (including integration of the accelerations resulting from the injected test signal).

(6)With the software executing normally, a step-force command shall be injected into the primary flight control causing it to move. The control position shall be sent to the host through normal mechanisms. When the host detects the command signal, a discrete index counter shall be initialized and then incremented by each of the software modules as the critical path is executed. The index shall only be updated if it contains the index number of the modules designated to run before it. This shall permit the software path to be traced with a signal that is not degraded by the simulated aircraft dynamics, thus providing a means to verify that each module of the critical path is executed in the proper order. The index shall also be used to inject a clean pitch, roll, or yaw step signal into the primary cue software at the normal point in the execution of that software. This clean step shall then be passed through the normal computing pathways to generate the primary cue responses that are recorded. The step signal shall be applied for __6a__ measurement repetitions.

(7)With the software executing normally, a step-force command signal shall be injected into the pitch, roll, and yaw axes of the primary flight control input, one axis at a time. The magnitude of the step signal shall be adjusted as necessary for each axis such that it is just large enough to ensure that there is no variation in measured delay attributable to changes in the magnitude of the input signal. The step signal shall be applied for __7a__ measurement repetitions.

(8)With the software executing normally, a sinusoidal command signal shall be injected into the pitch, roll, and yaw axes of the primary flight control input, one axis at a time. The magnitude and frequency of each sinusoidal signal shall be adjusted as necessary for each axis such that it results in an observably noise-free and linear response and produces a phase shift with sufficient resolution for the measurement. The sinusoidal signal shall be applied for a sufficient period to assure stable measurements. The phase angles of the primary cue responses relative to the command signal and relative to each other shall be recorded.

RATIONALE

This paragraph and its subparagraphs establish the worst-case temporal delay (or latency) permitted for the primary cues (visual, physical motion, and cockpit instrument displays). They also specify the worst-case temporal mismatch permitted among these cues (i.e., required cue synchronization or correlation).

Requirements Guidance:

1. Tailor the phrase following (1) to reflect the actual primary cuing suite being employed for this application. Commercial flight simulators require the three primary cuing systems listed.

Verification Guidance: *Choose one of the three alternative verification paragraphs. The first and second correspond to the commercial standard imposed by regulatory agencies for airplane and helicopter simulators, respectively. The third is more general, and allows for extensions from the regulatory standards that are often advisable for military simulation.*

If the first or second verification alternative (i.e., commercial regulatory standard for airplane or helicopter simulator, respectively) is chosen:

2. Tailor or delete the item(s) following (2) to be consistent with the requirement (e.g., the motion platform used in a specific application may not have all three angular degrees of freedom).

If the third verification alternative (i.e., the more general form) is chosen:

3. Tailor or delete items from the list of recorded signals following (3) to be consistent with the requirements for the application.

4. Choose the appropriate descriptor for the control signal to be recorded following (4). Commercial simulator applications record control deflection. For some military applications, control force may be more appropriate.

5. Tailor the definition for the lag associated with visual image presentation if desired. Since the value for each pixel in the image is updated and held at a constant value (neglecting effects such as phosphor decay) once every T seconds, the visual display output is essentially a zero-order sample-and-hold device. The definition provided is therefore consistent with the delay associated with a zero-order hold (i.e., a delay of T/2 seconds); it is the delay that would be measured using sinusoidal phase lags. However, other definitions of delay may be more appropriate -- depending on how this requirement is tailored. For example, if transient response were of primary interest, the definition might be, "Lags associated with visual image presentation shall be defined to be the delay until the onset of a change in the visual image."

6. The commercial regulatory tests used to be performed by comparing simulator response to aircraft response, with the same abrupt command input applied to the simulator as was applied to the aircraft, and then subtracting the delay contributed by the aircraft (as measured in flight) in order to arrive at the delay contributed by the simulator. This method not only inherently assumed that the simulator response would be exactly the same as the aircraft response, but also suffered from the problems associated with a human attempting to input a step (see Requirements Guidance (2) in 3.2.1.5.1). As a result, the regulatory agencies have adopted the new method included here.

The paragraph following (6) specifies the current commercial regulatory procedure for discrete-signal characterization of throughput delays and synchronization. This paragraph permits use of the third verification alternative, rather than using the first or second verification alternative, for verification against commercial standards; this provides some flexibility in tailoring the requirement while retaining the commercial standard test process. If it is not intended to replicate commercial test procedures, delete the paragraph following (6); do not retain this paragraph if the paragraph following (7) is retained, since the end-to-end results are redundant. If this paragraph is retained, specify the number of measurement repetitions in blank (6a); these repetitions are necessary due to the sampling uncertainty that arises with discrete test signals. No more than ten repetitions should be needed to obtain reasonable estimates for worst-case conditions.

Rather than subjecting the simulator to step inputs unnecessarily, it is recommended that the paragraph following (6) be deleted. Discrete-signal propagation verification can be better accomplished by analysis in accordance with Verification Guidance (7) of 3.2.1.5.1 (although analysis does not provide a measure of the transient response of the primary cue hardware). However, if the cue synchronization requirement includes a step (or abrupt) signal tolerance (i.e., if the sentence following (1) is retained in 3.2.1.5.2),

either this paragraph or the paragraph following (7) must be retained in order to obtain the necessary measurement data.

7. The paragraph following (7) provides a procedure for directly measuring discrete-signal throughput delays and synchronization. Do not retain this paragraph if the paragraph following (6) is retained, since the end-to-end results are redundant. If this paragraph is retained, specify the number of measurement repetitions in blank (7a); these repetitions are necessary due to the sampling uncertainty that arises with discrete test signals. No more than ten repetitions should be needed to obtain reasonable estimates for worst-case conditions.

Rather than subjecting the simulator to step inputs unnecessarily, it is recommended that the paragraph following (7) be deleted. Discrete-signal propagation verification can be better accomplished by analysis in accordance with Verification Guidance (7) of 3.2.1.5.1 (although analysis does not provide a measure of the transient response of the primary cue hardware). However, if the cue synchronization requirement includes a step (or abrupt) signal tolerance (i.e., if the sentence following (1) is retained in 3.2.1.5.2), either this paragraph or the paragraph following (6) must be retained in order to obtain the necessary measurement data.

8. If throughput latency or cue synchronization is to be characterized in terms of phase angle (i.e., if 3.2.1.5.1 retains the sentence following (3) or 3.2.1.5.2 retains the sentence following (2)), then the paragraph following (8) is to be retained. Otherwise, delete the paragraph following (8).

In conducting this test, it is important that the measured primary cue responses are reasonably free of noise and non-linear effects, as either will corrupt the phase angle measurements. The magnitude of the test signal needs to be selected such that the signal is significantly larger than the noise, but still does not exhibit significant non-linear effects such as saturation. Similarly, the frequency has to be adjusted to obtain a reasonably clean, linear test signal response.

There are reasons why it may be desirable to obtain these measurements at high frequencies. Lags due to higher-order dynamics that are not well approximated as pure time delays at lower frequencies will normally increase more rapidly than the phase lag for a pure time delay at higher frequencies; measurements at higher frequencies would then tend to capture worse-case conditions. Phase angle resolution increases with frequency; e.g., a phase tolerance of 12 degrees/Hz translates into a phase shift of 6 degrees at 0.5 Hz, but into 24 degrees at 2 Hz. On the other hand, since angular velocity scales directly with frequency and angular acceleration scales as the square of frequency, the higher frequencies will lead to higher velocities and accelerations. This, in turn, may cause some of the primary cue responses to be subject to velocity or acceleration limiting at higher frequencies. Overall, the signals used should be as high a frequency as practical, with consideration given to minimizing unnecessary equipment abuse. The most important consideration is a clean, linear response signal and enough resolution in the phase angle measurement to verify the requirement.

EXAMPLES

Example 1. A simulator for a cargo airplane that is to strictly meet FAA Level D standards.

3.2.1.5 Simulator Dynamic Response. Throughput latency and cue synchronization of the physical motion, visual, and cockpit instrument cue (hereafter referred to as the primary cues) responses to a control input at the pilot station shall be as specified in 3.2.1.5.1 and 3.2.1.5.2. This requirement shall be satisfied with the attenuation and lag effects of the aerodynamic forces and moments bypassed, but with the time lags associated with all computations retained.

4.2.1.2.1.5 Verification of Simulator Dynamic Response. This requirement shall be verified by test. Throughput latency and cue synchronization of the primary cue drives shall be verified by test in accordance with the procedures of the "Airplane Flight Simulator Evaluation Handbook" as follows:

Section 4a Simulator Pitch Response

Section 4a Simulator Roll Response
Section 4a Simulator Yaw Response

In the event of a conflict, the requirement as specified herein takes precedence over the "Airplane Flight Simulator Evaluation Handbook".

Example 2. A simulator for an AC-130H airplane that is to be used to rehearse Special Operations missions. A small, electrically-powered motion platform is to provide physical motion cues in the pitch and roll degrees of freedom. Throughput latency is to have no significant effect on pilot performance in the simulator. Cue asynchrony is to be small enough that all primary cues appear to occur simultaneously under normal workload conditions. Measurements of end-to-end latency and synchronization of the primary cues are to be obtained as a part of verification, but it is desired that simulator tests not unnecessarily subject the visual display or cockpit avionics systems to high g-onsets.

3.2.1.5 Simulator Dynamic Response. Throughput latency and cue synchronization of the physical motion, visual, and cockpit instrument cue (hereafter referred to as the primary cues) responses to a control input at the pilot station shall be as specified in 3.2.1.5.1 and 3.2.1.5.2. This requirement shall be satisfied with the attenuation and lag effects of the aerodynamic forces and moments bypassed, but with the time lags associated with all computations retained.

4.2.1.2.1.5 Verification of Simulator Dynamic Response. This requirement shall be verified by test. Throughput latency and cue synchronization of the primary cue drives shall be verified by test in accordance with the following procedure.

Time histories of the following input signal and primary cue responses shall be recorded simultaneously:

a. Control deflection signal.
b. Primary cockpit indication of aircraft attitude.
c. Motion cuing device acceleration or equivalent signal.
d. Visual position cue at the display system output.

Lags associated with visual image presentation shall be defined to be one-half of the imagery update period, where the imagery update period is the inverse of the image update rate.

The software shall be configured such that the normal calculations of aerodynamic forces and moments are bypassed, and the injected test signal is substituted in their stead. Otherwise, all software shall be configured for normal, operational execution (including integration of the accelerations resulting from the injected test signal).

With the software executing normally, a sinusoidal command signal shall be injected into the pitch, roll, and yaw axes of the primary flight control input, one axis at a time. The magnitude and frequency of each sinusoidal signal shall be adjusted as necessary for each axis such that it results in an observably noise-free and linear response and produces a phase shift with sufficient resolution for the measurement. The sinusoidal signal shall be applied for a sufficient period to assure stable measurements. The phase angles of the primary cue responses relative to the command signal and relative to each other shall be recorded.

3.2.1.5.1 Throughput Latency. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

The primary cuing systems shall respond to abrupt flight control inputs at the pilot's position within __1__ milliseconds of the time, but not before the time, when the aircraft would respond under the same conditions.

-OR-

(2)The time required for a step (or abrupt) signal to migrate from the pilot's control input to a corresponding primary cue shall not be greater than __2a__ milliseconds. (3)The sinusoidal response of any primary cue shall not exhibit a phase delay relative to the control input greater than __3a__.

4.2.1.2.1.5.1 Verification of Throughput Latency. This requirement shall be verified by (4) analysis and test. Test shall be conducted in accordance with 3.2.1.5. (5)The recorded delay between the onset of the control input signal and the primary cues and (6) the recorded phase angles of the primary cue responses relative to the command signal shall be used to verify conformance to the requirement. (7)Analysis of the end-to-end timing, including input signal sampling uncertainty, and the order of any software executed by the executive that contributes to the realtime simulation shall verify that the discrete-signal throughput latency conforms to the requirement.

RATIONALE

Commercial regulatory standards do not include delays attributable to the simulated aircraft. While this practice may be adequate for the relatively benign environment of commercial aviation, the practice of ignoring the aircraft equivalent delays will not generally hold up well to military simulations involving more demanding vehicle-control tasks. The ensuing guidance should be considered for military simulation applications.

A recent study evaluating the effects of delay on pilot control looked at both fighter and transport classes of aircraft. The findings in regard to the performance of a demanding task were the same for either class. That is, the maximum delay permissible before the ratings went from Level 1 flying qualities (i.e., satisfactory) to Level 2 (i.e., deficient) was about 150 milliseconds for both fighter and transport-class aircraft. Unlike the commercial definition of delay, this 150 milliseconds includes the contributions of the aircraft equivalent delay. This investigation is described in the following two papers: Bailey, Knotts Horowitz, & Malone, 1987, "Effect of Time Delay on Manual Flight Control and Flying Qualities During In-flight and Ground-based Simulation", AIAA Paper Number 87-2370, and Knotts & Bailey, 1988, "Ground Simulator Requirements Based on In-flight Simulation", AIAA Paper Number 88-4609-CP.

In a paper entitled "System Integration", Dr. Grant McMillan summarizes the results of the above investigation and other available data in his recommendations for permissible latency. This paper is included in the course notes for the "Eleventh Annual Flight and Ground Vehicle Simulation Update - 1995" offered by the Office of Continuing Education, Watson School of Engineering, State University of New York, Binghamton NY. (This is not included in editions of the course notes published after January 1995.) The recommendations are repeated here.

McMillan's first Rule-of-thumb: To ensure Level 1 handling qualities in the simulator, the sum of aircraft model equivalent delays, aircraft model transport delays, and added simulator delays should not exceed 150 milliseconds. This value is up to 100 milliseconds more stringent than the FAA Level C and D values for airplane simulators since it considers the delays included in the aircraft model.

McMillan's second Rule-of-thumb: To minimize delay effects on pilot performance in the simulator, the sum of aircraft model delays and simulator delays should not exceed 200 milliseconds. For an aircraft that just meets MIL-F-8785C "Flying Qualities of Piloted Airplanes", this value is equivalent to 100 milliseconds and is the value most likely to be quoted as the maximum acceptable delay among knowledgeable experts. (Note that MIL-F-8785C adopted 100 milliseconds as the maximum total equivalent and/or transport delay that may be included between control input and aircraft response; this requirement was brought about due to the advent of superaugmented aircraft.)

McMillan's third Rule-of-thumb: To promote good transfer of training, the sum of aircraft model delays and simulator delays should not exceed 300 milliseconds.

McMillan's fourth Rule-of-thumb: No delay guidelines can be proposed with respect to simulator sickness issues.

McMillan's fifth Rule-of-thumb: The same guidelines apply to cargo and fighter aircraft, since military transport pilots often have high task demands.

Requirements Guidance: *Choose one of the two alternative requirements paragraphs.*

The first alternative corresponds to the commercial standard imposed by regulatory agencies. Throughput latency is defined by the "Airplane Flight Simulator Evaluation Handbook" as, "the delay encountered by a step signal migrating from the pilot's control through the control loading electronics and interfacing through all the essential simulation software modules in the correct order using a handshake protocol and finally producing outputs to the motion, visual and instrument systems via the normal output interfaces." This definition applies in the context of the first alternative.

The second alternative allows for extensions from the regulatory standards that may be more desirable for military applications. Throughput latency is defined in a broader sense in the context of the second alternative. It can include not only the simulator-induced delays encountered by a step signal, but also the sinusoidal phase lags contributed by continuous (i.e., analog) components of the simulator. It can also account for the delays attributable to the aircraft, in accordance with the recommendations of the rationale introductory material.

If the first alternative (i.e., commercial regulatory standard) is chosen:

1. Place the worst-case system latency permitted in blank (1). Level A and B airplane simulators require a response within 300 milliseconds; Level B helicopter simulators require a response within 150 milliseconds. Level C and D airplane simulators require a response within 150 milliseconds; Level C and D helicopter simulators require a response within 100 milliseconds.

If the second alternative (i.e., the more general form) is chosen:

2. Step-signal latency provides information regarding how transients will propagate through the simulation. However, the motor-control bandwidth of a human operator is limited to about 3 Hz; when combined with the dynamics of the flight control system and the vehicle, the human-vehicle bandwidth will generally not exceed 2 Hz. With this bandwidth limitation, a human pilot cannot inject a sharp "step input". When a human attempts to input a step, the low-pass nature of the human-vehicle dynamics swamps out the high frequency effects that would be of interest (such as delays introduced by predictive algorithms that require a number of past values -- see Gum and Martin, 1987, "The Flight Simulator Time Delay Problem", AIAA Paper Number 87-2369-CP, for further insight). Therefore, use of step signals as the primary characterization of simulator delays is not recommended. Characterizing throughput delays by measuring their contribution to the phase shift of sinusoidal test signals (see Requirements Guidance (3) below) is probably more relevant to continuous, precision flight control (where simulation delay is more of a concern) than are step signals (which are more analogous to the larger, highly practiced -- i.e., precognitive -- types of control where delay is a lesser concern). Still, it may sometimes be useful to retain a specification on step-signal propagation delay and synchronization as a cross-check to sinusoidal measures since the latter will not be reliably measured if nonlinear effects are not reduced to levels that do not significantly distort the sinusoidal response; it is recommended that verification of a step-signal specification be conducted by analysis rather than test.

If no specification regarding discrete signal propagation delay is to be imposed, delete the sentence following (2). Otherwise, retain the sentence following (2), and place the worst-case system latency permitted in blank (2a); this is required by commercial regulatory standards. See Requirements Guidance (1) for the latencies permitted by commercial regulatory agencies. If it is intended that discrete-signal throughput latency be verified by analysis, some allowance should be made for the fact that analysis will not capture the effect of lags or delays in the primary cue drives.

3. One of the principal advantages of characterizing delay by using sinusoidal measurements is that this technique not only captures the effects of pure time delays -- it captures the equivalent delay introduced

by analog components as well. Discrete system characterizations do not handle the effects of phase lags well unless the command input consists of steps large enough to elicit responses that clearly stand out from the noise. The traditional simulator abrupt-change technique has been to measure the delay between a pilot-induced "step" input and the onset of a response; such a measure relies heavily on subjective judgment due to the presence of system noise and the effects of hardware and simulated flight control and vehicle lags. In addition, sinusoidal measurements do not abuse the equipment as much as do step inputs, and are not subject to the sampling uncertainty to which step inputs are subject. Another advantage to sinusoidal measurements is that the preponderance of the manual control literature reporting the effects of time delay on human operator response is based on sinusoidal stimuli. Since the delays measured in the steady-state frequency domain (i.e., with sinusoidal stimulation) are not the same as the transient or onset responses measured with discrete signals (i.e., steps), delays measured using sinusoids can be more directly related to the manual control literature. For further insight, see Gum and Martin, 1987, "The Flight Simulator Time Delay Problem", AIAA Paper Number 87-2369-CP.

If there is to be no time delay specification in terms of the steady-state frequency domain (i.e., sinusoidal inputs), delete the sentence following (3). Otherwise, retain the sentence following (3) and fill in blank (3a) in accordance with the following guidance.

The phase delay, ø, corresponding to a time delay, T, can be calculated as follows:

$$ø = 360 * T * f$$

where ø is in degrees, T in seconds, f in Hz or cycles/second, with 360 degrees/cycle.

*The phase angle normalized to frequency in Hz is: (ø/f) = 360 * T degrees/Hz.*

For blank (3a):

If the equivalent delay of the aircraft is not to be included in the tolerance, blank (3a) should read, "__3b__ degrees/Hz." Blank (3b) is filled in with the phase angle -- normalized to frequency in Hz -- corresponding to the worst-case system latency permitted. Level A and B airplane simulators require a response within 300 milliseconds (or 108 degrees/Hz); Level B helicopter simulators require a response within 150 milliseconds (or 54 degrees/Hz). Level C and D airplane simulators require a response within 150 milliseconds (or 54 degrees/Hz); Level C and D helicopter simulators require a response within 100 milliseconds (or 36 degrees/Hz).

If the equivalent delay of the aircraft is to be included in the tolerance, blank (3a) should read, "[(0.36) x (__3b__ milliseconds - t milliseconds)] degrees/Hz, where t is the total aircraft equivalent and transport delay included between control input and aircraft response, in accordance with the approved design criteria." The maximum permitted value for the sum of the simulator delays and aircraft delays is placed in blank (3b).

Verification Guidance:

4. If the sentence following (7) is deleted, delete the phrase "analysis and" following (4).

5. If a step-signal hardware response measurement is required (i.e., if the first or second verification alternative of 3.2.1.5 is used or if (6) or (7) of the third alternative of 3.2.1.5 is used), retain the phrase following (5). Otherwise, delete the phrase "the recorded delay between the onset of the control input signal and the primary cues" that follows (5).

6. If a sinusoidal-response measurement is required (i.e., (8) of the third alternative of 3.2.1.5 is used), retain the phrase following (6). Otherwise, delete the phrase "the recorded phase angles of the primary cue responses relative to the command signal" that follows (6).

7. If the step-signal latency is to be determined by analysis in accordance with the recommendation of Requirements Guidance (2) above, retain the sentence following (7). Otherwise, delete the sentence

following (7). Analysis must account for analog input sampling uncertainties so that the end-to-end worst-case latency derived via analysis is consistent with that that would be measured using step inputs. However, analysis will not capture the effects of time delays or lags in the primary cue drives; any allowances for this should be considered in the tolerance value specified in blank (2a).

EXAMPLES
Example 1. A simulator for a cargo airplane that is to strictly meet FAA Level D standards.

3.2.1.5.1 Throughput Latency. The primary cuing systems shall respond to abrupt flight control inputs at the pilot's position within 150 milliseconds of the time, but not before the time, when the aircraft would respond under the same conditions.

4.2.1.2.1.5.1 Verification of Throughput Latency. This requirement shall be verified by test. Test shall be conducted in accordance with 3.2.1.5. The recorded delay between the onset of the control input signal and the primary cues relative to the command signal shall be used to verify conformance to the requirement.

Example 2. A simulator for an AC-130H airplane that is to be used to rehearse Special Operations missions. A small, electrically-powered motion platform is to provide physical motion cues in the pitch and roll degrees of freedom. Throughput latency is to have no significant effect on pilot performance in the simulator. Cue asynchrony is to be small enough that all primary cues appear to occur simultaneously under normal workload conditions. Measurements of end-to-end latency and synchronization of the primary cues are to be obtained as a part of verification, but it is desired that simulator tests not unnecessarily subject the visual display or cockpit avionics systems to high g-onsets. [NOTE: A conservative value of 100 milliseconds is being used for the discrete-signal propagation tolerance; since this will be verified by analysis, some allowance is being made for the fact that analysis will not capture the effect of lags or delays in the primary cue analog drives. The tolerance being used for the end-to-end sinusoidal delay measurement is based upon the introductory guidance in the rationale, and the requirement to minimize delay effects on pilot performance in the simulator.]

3.2.1.5.1 Throughput Latency. The time required for a step (or abrupt) signal to migrate from the pilot's control input to a corresponding primary cue shall not be greater than 100 milliseconds. The sinusoidal response of any primary cue shall not exhibit a phase delay relative to the control input greater than [(0.36) x (200 milliseconds - t milliseconds)] degrees/Hz, where t is the total aircraft equivalent and transport delay included between control input and aircraft response, in accordance with the approved design criteria..

4.2.1.2.1.5.1 Verification of Throughput Latency. This requirement shall be verified by analysis and test. Test shall be conducted in accordance with 3.2.1.5. The recorded phase angles of the primary cue responses relative to the command signal shall be used to verify conformance to the requirement. Analysis of the end-to-end timing, including input signal sampling uncertainty, and the order of any software executed by the executive that contributes to the realtime simulation shall verify that the discrete-signal throughput latency conforms to the requirement.

3.2.1.5.2 Cue Synchronization. CHOOSE ONE OF THE FOLLOWING THREE ALTERNATIVES:

All primary cuing systems shall respond to abrupt flight control inputs at the pilot's position within the time permitted for throughput latency, but visual scene changes shall not occur before the motion onset.

-OR-

All primary cuing systems shall respond to abrupt flight control inputs at the pilot's position within the time permitted for throughput latency. Visual change may start before the motion response, but motion cuing must occur before completion of the visual scan of first video field containing different information.

-OR-

(1)For a step (or abrupt) signal input, the difference in throughput latency between any two primary cues shall not be greater than __1a__ milliseconds. (2)For a sinusoidal signal input, the difference in phase angle relative to the command signal between any two primary cues shall not be greater than __2a__ degrees/Hz. (3)The throughput latency for the physical motion cue shall not be greater than the throughput latency for the visual cue.

4.2.1.2.1.5.2 Verification of Cue Synchronization. This requirement shall be verified by (4) analysis and test. Test shall be conducted in accordance with 3.2.1.5. Differences in (5) discrete throughput delays and (6) phase angles among the primary cue responses shall be used to verify conformance to the requirement. (7)Analysis of the end-to-end timing, including input signal sampling uncertainty, and the order of any software executed by the executive that contributes to the realtime simulation shall verify that the discrete-signal synchronization conforms to the requirement.

RATIONALE
A dilemma associated with cue synchronization is whether to display a cue as soon as it is available, or to delay it (if necessary) to await the response of the slower cuing system(s). The commercial airplane standards are based on the premise that acceleration must occur before the visual world (i.e., simulated aircraft attitude) changes in order to preserve real-world phase relationships and realism. However, if one consults the human performance literature, another option is suggested. Human performance data indicate that for heteromodal (i.e., visual, tactile, and auditory) stimulus sequences, subjects cannot reliably detect the stimulus order for stimulus intervals of less than 20 milliseconds (see Entry 5.1022 in "Engineering Data Compendium, Human Perception and Performance"). This suggests that it would be better to present whichever cue is available as soon as possible, rather than delaying one cue to wait for another, so long as all cues are presented within a 20 millisecond interval (it is likely that a somewhat larger interval could be tolerated in practice, since the laboratory data do not account for the effect of workload).

Requirements Guidance: *Choose one of the three alternative requirements paragraphs.*

The first two alternatives correspond to commercial regulatory standards and the regulatory agencies' realism paradigm discussed in the rationale introductory paragraph above. These alternatives require that visual cues be delayed until the physical motion cue catches up, if necessary. The first alternative, for airplane flight simulators, corresponds to AC 120-40C. The second alternative, for helicopter flight simulators, corresponds to AC 120-63.

The third alternative is a more general, extensible form. If the third alternative is chosen:

1. If there is no specification regarding discrete signal propagation delay (see the Requirements Guidance (2) of 3.2.1.5.1) or if no specification is required in regard to step-signal synchronization, delete the sentence following (1). If a sinusoidal phase-shift difference specification is included in accordance with the guidance for (6) below, it is recommended that the sentence following (1) be deleted in order to prevent any mismatch specification conflicts from arising (step inputs and sinusoidal inputs measure different components of a system's response; the steady-state sinusoidal response is probably the more relevant).

Otherwise, consider retention of the sentence following (1). If the requirement is retained, place the maximum permitted temporal mismatch for the primary cues in blank (1a). A value that has been used on some military simulators in the past is 35 milliseconds; 35 milliseconds is a reasonable value even though human performance data have shown that the temporal order of the onset of heteromodal stimuli can be identified for stimulus intervals as low as 20 milliseconds (see the rationale introductory paragraph above).

2. If there are no recorded cue synchronization data in terms of the steady-state frequency domain (i.e., (8) of the third alternative of 3.2.1.5 is not used), delete the sentence following (2). Otherwise, retain the sentence following (2), and place the phase angle -- normalized to frequency in Hz -- corresponding to the worst-case cue mismatch permitted in blank (2a).

The phase angle, ø, corresponding to a time period, T, can be calculated as follows:

$$\phi = 360 * T * f$$

where ø is in degrees, T in seconds, f in Hz or cycles/second, with 360 degrees/cycle.

*The phase angle normalized to frequency in Hz is: (ø/f) = 360 * T degrees/Hz.*

For blank (2a): See the rationale introductory paragraph above for a discussion of permissible cue mismatches. A temporal mismatch of 35 milliseconds is equivalent to 12.6 degrees/Hz. A temporal mismatch of 20 milliseconds is equivalent to 7.2 degrees/Hz.

3. If the regulatory agencies' realism paradigm discussed in the rationale introductory paragraph above is to be imposed, retain the sentence following (3). Before this requirement is imposed, the relevant discussion in the rationale introductory paragraph above should be carefully considered. If any cue is to be displayed as soon as it becomes available (subject to any synchronization constraints imposed by Requirements Guidance (1) and (2)), delete the sentence following (3).

Verification Guidance:

4. If the sentence following (7) is deleted, delete the phrase "analysis and" following (4).

5. If a step-signal hardware response measurement is required (i.e., if the first or second verification alternative of 3.2.1.5 is used or if (6) or (7) of the third alternative of 3.2.1.5 is used), retain the phrase following (5). Otherwise, delete the phrase "discrete throughput delays" that follows (5).

6. If a sinusoidal-response measurement is required (i.e., (8) of the third alternative of 3.2.1.5 is used), retain the phrase following (6). Otherwise, delete the phrase "phase angles among the primary cue responses" that follows (6).

7. If the step-signal synchronization is to be determined by analysis in accordance with the recommendation of Requirements Guidance (2) of 3.2.1.5.1, retain the sentence following (7). Otherwise, delete the sentence following (7).

EXAMPLES

Example 1. A simulator for a cargo airplane that is to strictly meet FAA Level D standards.

3.2.1.5.2 Cue Synchronization. All primary cuing systems shall respond to abrupt flight control inputs at the pilot's position within the time permitted for throughput latency, but visual scene changes shall not occur before the motion onset.

4.2.1.2.1.5.2 Verification of Cue Synchronization. This requirement shall be verified by test. Test shall be conducted in accordance with 3.2.1.5. Differences in discrete throughput delays shall be used to verify conformance to the requirement.

Example 2. A simulator for an AC-130H airplane that is to be used to rehearse Special Operations missions. A small, electrically-powered motion platform is to provide physical motion cues in the pitch and roll degrees of freedom. Throughput latency is to have no significant effect on pilot performance in the simulator. Cue asynchrony is to be small enough that all primary cues appear to occur simultaneously under normal workload conditions. Measurements of end-to-end latency and synchronization of the primary cues are to be obtained as a part of verification, but it is desired that simulator tests not unnecessarily subject the visual display or cockpit avionics systems to high g-onsets.

3.2.1.5.2 Cue Synchronization. For a sinusoidal signal input, the difference in phase angle relative to the command signal between any two primary cues shall not be greater than 12.6 degrees/Hz.

4.2.1.2.1.5.2 Verification of Cue Synchronization. This requirement shall be verified by analysis and test. Test shall be conducted in accordance with 3.2.1.5. Differences in phase angles among the primary cue responses shall be used to verify conformance to the requirement. Analysis of the end-to-end timing, including input signal sampling uncertainty, and the order of any software executed by the executive that contributes to the realtime simulation shall verify that the discrete-signal synchronization conforms to the requirement.

3.2.1.6 Maximum Software Transport Delays. The time required for the accomplishment of any event or activity assigned to an asynchronous task shall not be greater than the corresponding maximum software transport delay specified below.
__1__

4.2.1.2.1.6 Verification of Maximum Software Transport Delays. This requirement shall be verified by test. Verification of this requirement shall be accomplished in conjunction with the verification of total spare time, in accordance with 4.2.1.4.2.

RATIONALE
Requirements Guidance: *This requirement establishes the maximum time permitted for the accomplishment of asynchronous tasks. This is specific to a design, and will normally be defined during the design process.*

1. The maximum delays permitted before the system accomplishes particular types of asynchronous tasks should be listed in blank (1). This is intended to be a set of tolerances, rather than a single tolerance value. Tolerances may be assigned to the accomplishment of specific events and activities, or to classes of events and activities, or both. The intent is that a ceiling be defined for the time that it will take to accomplish any asynchronous task, and that these times be reasonable and practical from both a designer's and a user's perspective.

Verification Guidance: *Various asynchronous tasks should be initiated during the conduct of the verification of flexibility and expansion as required by 4.2.1.4.2. Objective and subjective time measurements, in conjunction with the time burner test, should verify that all asynchronous tasks are accomplished within their required times without over-running frame times or violating the spare time requirement of this specification.*

Process Guidance: *The times to be allowed for the accomplishment of various asynchronous tasks will be defined as a part of the design process. These times should be mutually agreed upon at technical design reviews during the simulator development.*

If both a system specification and PIDS are used on a program, then this paragraph need not be included in the System Specification. If only one specification is used for the device, then it may be necessary to make this requirement "TBD" and define a statement of work process to rewrite it later. If both specifications are used, the statement of work should task development of the applicable PIDS requirement.

EXAMPLES
The following values and categories are strictly notional. The actual values and categories should be logically based on the design solution and mutually agreed-upon delay tolerances.

3.2.1.6 Maximum Software Transport Delays. The time required for the accomplishment of any event or activity assigned to an asynchronous task shall not be greater than the corresponding maximum software transport delay specified below.

Mission initialization: 5.0 minutes

Stabilization: 30.0 seconds

Malfunction activation: 2.0 seconds

Instructor station page change and update: 1.5 seconds

et cetera

et cetera

3.2.1.7 Timestamp Accuracy. The simulator shall support timestamps in accordance with IEEE Standard 1278. The timestamp shall be synchronized with the clocks of other networked simulators using the same clock-synchronization source to within __1__ microseconds.

4.2.1.2.1.7 Verification of Timestamp Accuracy. This requirement shall be verified by analysis and demonstration. Analysis shall verify that the design is consistent with the requirement. Demonstration shall verify that the timestamp conforms to IEEE Standard 1278.

RATIONALE
This requirement is applicable to simulators that are to be used in long-haul networked simulations. IEEE Standard 1278 "Standard for Information Technology--Protocols for Distributed Interactive Simulation Applications" defines the format and implementation of timestamps.

The concept of Distributed Interactive Simulation (DIS) is to permit remotely operating simulators to participate interactively in a common synthetic environment. Time delays are introduced due to the large distances over which these simulators must communicate. While these delays arise from several sources, clock error is a source that can be controlled in order to eliminate systematic errors in the dead reckoning of states among networked entities (see Katz, "Event correlation for networked simulators", Journal of Aircraft, 32(3), pp 515-519, May-June 1995). Control of clock error requires that all simulators playing in an exercise have their clocks synchronized to a common source. Radio signals broadcast by the National Institute of Standards and Technology (NIST) from its radio stations WWV, WWVB, and WWVH permit a clock accuracy of up to 1 millisecond to be achieved, but tightly coupled interactive scenarios such as formation flight require much better accuracy. For that reason, the global positioning system (GPS) is the recommended time-synchronization source.

Requirements Guidance: *This requirement only applies if this simulator is to be used in networked simulations using DIS protocol data units (PDUs). If this simulator is not to be used in DIS applications, delete this paragraph. Otherwise, continue in accordance with the following guidance.*

1. Specify the clock synchronization tolerance in blank (1). Researchers who have studied this issue recommend a tolerance of 100 microseconds. This value would allow one clock to serve simulators within a 30 kilometer radius, assuming speed-of-light (i.e., 300 meters per microsecond) propagation.

Verification Guidance: *Demonstration can verify that the simulator is capable of receiving a clock synchronization signal from an acceptable source, synchronizing its clock, and formatting event timestamps properly in the PDUs. Analysis of the design should readily verify that propagation delays from the synchronization-time source to this simulator are the same as to the other simulators with which it will interact, to within the required tolerance.*

3.2.2 Physical Characteristics. The simulator shall consist of:
__1__.
The simulator __2__.

4.2.1.2.2 Verification of Physical Characteristics. This requirement shall be verified by inspection.

RATIONALE
Requirements Guidance:

1. This blank should describe the principal physical entities (cockpits, crew stations, instructor stations, motion bases, etc.) which make up the simulator, as well as the physical relationships between them.

2. This blank should describe any requirements, such as weight or dimensional limits, which establish boundary conditions necessary to assure physical compatibility and which are not defined by interface requirements, design and construction requirements, or referenced drawings. The sentence may be deleted if there are no such requirements.

Care must be taken to avoid unnecessarily restricting size or weight. Dimensions must be consistent with other requirements (e.g., the height must be consistent with visual display requirements).

EXAMPLES
Example 1. Multi-station simulator with size constraint.

3.2.2 Physical Characteristics. The simulator shall consist of:

a. Four separately enclosed student stations.

b. Two instructor stations.

c. A central computer complex.

The simulator shall fit in a 30 foot wide by 30 foot long by 30 foot high room.

Example 2. Weapons system trainer without size constraint.

3.2.2 Physical Characteristics. The simulator shall consist of:

a. A cockpit with visual display on a motion base.

b. An on-board instructor station at the rear of the cockpit, within the cockpit enclosure.

c. A remote instructor station.

d. A central complex for computer and electronic cabinets.

Example 3. Simulator similar to F-15/F-16 Unit Training Device with small cockpit and size constraints.

3.2.2 Physical Characteristics. The simulator shall consist of:

a. An open cockpit.

b. An instructor station that can be operated by either a pilot sitting in the cockpit or an instructor sitting outside the cockpit.

The simulator footprint shall fit and operate in an eight foot by ten foot area. The height of the simulator shall not exceed eight feet. The simulator shall be broken into pieces such that each piece can be carried through a 60 inch wide hallway and stairs, as well as a 36 inch wide door.

3.2.2.1 Power. The simulator shall operate on __1__ phase, __2__ hertz, __3__ volt, __4__ power. In addition the following power requirements shall apply.

a. There shall be single point turn on for the simulator.

b. The power system shall facilitate access for maintenance and modification.

c. Circuit breakers shall protect all simulator equipment from power overloads. No circuit breakers shall be used as regular on/off switches, unless specifically designed to act as such.

d. All of the simulator equipment shall be protected from damage and alteration of characteristics due to power failures or other power conditions.

e. The simulator shall have separate grounds for primary power, analog signals, and digital signals.

f. Any backup power shall have a switch to permit deactivation in the event of planned power shutdown.

__5__.

4.2.1.2.2.1 Verification of Power. This requirement shall be verified by analysis, (6) demonstration, and inspection. The design of the power system shall be analyzed to ensure easily attained access for maintenance and modification. (6)Power factor and line balance shall be demonstrated by measuring the quantities during a period when simulator operation approximates intended use. Other requirements shall be verified by inspection of the simulator.

RATIONALE

This paragraph should usually be provided by the contractor unless there are major facility constraints. Any choices must be compatible with overall simulator design and the components of that design. Safety issues, such as conformance to National Electrical Manufacturers Association (NEMA) standards or National Electrical Code should be included in paragraph 3.3.6 "Safety" (note that the National Electrical Code is included under NFPA standards, and need not be called out separately).

Requirements Guidance:

1. Fill in the blank with "single" phase or "three" phase. Three phase will be necessary where there is a large power load or large motors are required. Single phase is appropriate otherwise.

2. Specify the operating frequency. Fill in the blank with "50", "60", or "50 and 60". 50 hertz operation is necessary for many overseas locations.

3. Specify the operating voltage; the usual choices are "120/208" or "277/480" for three phase power and "110" or "220" for single phase.

4. Specify the current capacity. Specify the type of connection for a three-phase system (the usual choice for three phase connections is wye-connected, four wire).

5. Add any of the following additional subparagraphs as appropriate:

a. "A utility power system shall provide power to turn on the lights and power outlets when the simulator power is off. The outlets shall be three wire grounded type. The utility power system shall have its own separate ground."

This requirement is appropriate for large simulators, in closed crew enclosures, and locations where facility power cannot be conveniently applied for simulator maintenance.

b. "All units in the simulator shall have indicator lights to indicate when power is on."

This requirement is appropriate for simulators with several cabinets when power application is not obvious.

c. "The power factor shall be 85 percent or greater, measured at the primary power source."

This requirement should be included when large motors are used in the simulator. The power factor without motors should be close to unity, and this requirement is unnecessary.

d. "Unbalanced line currents shall not exceed 7.5 percent of the average, simultaneously measured line current."

This requirement should apply to three-phase systems.

e. "Power conditioning equipment shall minimize effects of power interrupts and disturbances."

This requirement is appropriate if the local power supply is of poor quality or thunderstorms are frequent.

Verification Guidance:

6. Delete the word "demonstration" and the sentence "Power factor and line balance shall be ..." if power factor and line balance requirements are not included.

EXAMPLES
Example 1. A small part-task trainer.

3.2.2.1 Power. The simulator shall operate on single phase, 50 and 60 hertz, 110 volt, 50 ampere power. In addition the following power requirements shall apply.

a. There shall be single point turn on for the simulator.

b. The power system shall facilitate access for maintenance and modification.

c. Circuit breakers shall protect all simulator equipment from power overloads. No circuit breakers shall be used as regular on/off switches, unless specifically designed to act as such.

d. All of the simulator equipment shall be protected from damage and alteration of characteristics due to power failures or other power conditions.

e. The simulator shall have separate grounds for primary power, analog signals, and digital signals.

f. Any backup power shall have a switch to permit deactivation in the event of planned power shutdown.

4.2.1.2.2.1 Verification of Power. This requirement shall be verified by analysis and inspection. The design of the power system shall be analyzed to ensure easily attained access for maintenance and modification. Other requirements shall be verified by inspection of the simulator.

Example 2. A complex weapons system trainer.

3.2.2.1 Power. The simulator shall operate on three-phase, 60 hertz, 277/480 volt, wye-connected, four wire, 150 ampere per phase power. In addition the following power requirements shall apply.

a. There shall be single point turn on for the simulator.

b. The power system shall facilitate access for maintenance and modification.

c. Circuit breakers shall protect all simulator equipment from power overloads. No circuit breakers shall be used as regular on/off switches, unless specifically designed to act as such.

d. All of the simulator equipment shall be protected from damage and alteration of characteristics due to power failures or other power conditions.

e. The simulator shall have separate grounds for primary power, analog signals, and digital signals.

f. Any backup power shall have a switch to permit deactivation in the event of planned power shutdown.

g. A utility power system shall provide power to turn on the lights and power outlets when the simulator power is off. The outlets shall be three wire grounded type. The utility power system shall have its own separate ground.

h. All units in the simulator shall have indicator lights to indicate when power is on.

i. The power factor shall be 85 percent or greater, measured at the primary power source.

j. Unbalanced line currents shall not exceed 7.5 percent of the average, simultaneously measured line current.

k. Power conditioning equipment shall minimize effects of power interrupts and disturbances.

4.2.1.2.2.1 Verification of Power. This requirement shall be verified by analysis, demonstration, and inspection. The design of the power system shall be analyzed to ensure easily attained access for maintenance and modification. Power factor and line balance shall be demonstrated by measuring the quantities during a period when simulator operation approximates intended use. Other requirements shall be verified by inspection of the simulator.

3.2.2.2 Emergency Off. Easily recognizable switches shall be provided to disconnect all electrical power in accordance with the safety requirements of this specification. (1)Emergency Off switches shall be located at __(2)__.

4.2.1.2.2.2 Verification of Emergency Off. This requirement shall be verified by demonstration. Each switch shall be activated.

RATIONALE

AFOSH Standard 127-118 requires that, "A means to disconnect electrical power to the entire training system shall be provided at all IOS and at other key locations on the training system." AFOSH Standard 127-118 is invoked by paragraph 3.3.6 "Safety". This "Emergency Off" paragraph should specify the appearance and location of the switches required by the AFOSH standard. Note that the AFOSH standard does not require emergency off switches per se; for a small system, this requirement could be satisfied by a prominent Power On/Off switch.

Requirements Guidance:

1. Delete the sentence following (1) for small simulators where all simulator power can be quickly disconnected by turning the power switch to "Off." Retain this sentence for large simulators that are spread out over large areas such that emergencies might not be detected at all locations, or when multiple power sources are used.

2. Specify the location of the switches if the sentence following (1) is retained. For a system specification it may be appropriate to state the location in general terms. The wording used must be consistent with -- and supplementary to (i.e., identify "key locations") -- that of AFOSH Standard 127-118 (cited above).

Process Guidance: *If locations are not specified, there should be a process that locates the switches. This should be done in conjunction with the statement of work tasking that invokes application of a tailored MIL-STD-882. The statement of work must also assure that the switch locations, once identified via the system safety program, are documented in this specification.*

EXAMPLES
Example 1. General locations are identified, as would be required by a system specification.

3.2.2.2 Emergency Off. Easily recognizable switches shall be provided to disconnect all electrical power in accordance with the safety requirements of this specification. Emergency Off switches shall be located at points in the simulator and facility where rapid communication with other locations is difficult.

Example 2. Specific locations are identified, as would be required in a PIDS.

3.2.2.2 Emergency Off. Easily recognizable switches shall be provided to disconnect all electrical power in accordance with the safety requirements of this specification. Emergency Off switches shall be located at the cockpit, at the instructor console and in the pump room.

3.2.2.3 Maintenance Intercom. A maintenance intercom shall provide communication between physically separated simulator locations for maintenance purposes. (1)Intercom stations shall be located at ______.

4.2.1.2.2.3 Verification of Maintenance Intercom. This requirement shall be verified by demonstration that includes operation and communication at each location.

RATIONALE
This requirement is appropriate only when the simulator is spread out over a large area and communication over that area is necessary to support maintenance activities. It is recommended that the need for this requirement be determined by the simulator developer rather than the Air Force, since the contractor will have responsibility for maintenance.

Requirements Guidance:

If the requirement is not appropriate replace the entire paragraph with "Not applicable."

1. The sentence following (1) should be deleted in a system specification. In a Prime Item Development Specification the locations of intercom stations should be specified.

Verification Guidance: *If this requirement is "not applicable", replace the verification paragraph with "Verification of this requirement is not applicable."*

Process Guidance: *If locations are not specified, the statement of work should define a process that locates the intercom stations and then updates this specification to document the locations.*

EXAMPLES
Example 1. A system specification for a large simulator with spread-out components.

3.2.2.3 Maintenance Intercom A maintenance intercom shall provide communication between physically separated simulator locations for maintenance purposes.

Example 2. A PIDS for a large simulator with spread-out components.

3.2.2.3 Maintenance Intercom A maintenance intercom shall provide communication between physically separated simulator locations for maintenance purposes. Intercom stations shall be located at the cockpit, at the instructor console and in the pump room.

Example 3. System specification or PIDS for a small simulator such as a Unit Training Device.

3.2.2.3 Maintenance Intercom. Not applicable

4.2.1.2.2.3 Verification of Maintenance Intercom. Verification of this requirement is not applicable.

3.2.3 Reliability. Reliability of the simulator shall be consistent with availability requirements.

4.2.1.2.3 Verification of Reliability. This requirement shall be verified by analysis. If the simulator satisfies the availability requirement, this requirement is met. If the simulator fails to meet the availability requirement, then data shall be analyzed to assure that reliability is adequate.

RATIONALE
With contractor logistics support, extensive use of off-the-shelf components, and an availability guarantee, reliability should not be a major item of concern. The contractor should be free to make all trade-offs, so long as the required availability is achieved.

Process Guidance: *Any requirements for a reliability program should be included in the Statement of Work.*

3.2.4 Maintainability. Maintainability of the simulator shall be consistent with availability requirements.

4.2.1.2.4 Verification of Maintainability. This requirement shall be verified by analysis. If the simulator satisfies the availability requirement, this requirement is met. If the simulator fails to meet the availability requirement, then data shall be analyzed to assure that maintainability is adequate.

RATIONALE
With contractor logistics support, extensive use of off-the-shelf components, and an availability guarantee, maintainability should not be a major item of concern. The contractor should be free to make all trade-offs, so long as the required availability is achieved.

Process Guidance: *Any requirements for a maintainability program should be included in the Statement of Work.*

3.2.5 Availability. The simulator availability shall be __1__. Availability is defined as __2__.

4.2.1.2.5 Verification of Availability. CHOOSE ONE OF THE THREE FOLLOWING ALTERNATIVES:

This requirement shall be verified by analysis. Component reliability and maintainability shall be estimated. The logistics system shall be modeled and availability verified.

-OR-

This requirement shall be verified by test. The simulator shall be tested __3__, during which time it shall be operated in a manner closely approximating normal use.

-OR-

This requirement shall be verified by test. The simulator shall be tested __3__, during which time it shall be fully utilized by actual using command aircrews.

RATIONALE

Although the MIL-STD-490B format does not admit to an "Availability" paragraph at the PIDS level, this requirement should nonetheless be included in the PIDS for Flight Simulators. In a contractor logistics support (CLS) environment, availability is really the user's "bottom line" so far as reliability and maintainability are concerned.

Availability is a function of the design, the logistic support system, and the skill and dedication of the people maintaining the device. Most simulators have CLS and an availability guarantee. This guarantee persists throughout the life of the simulator. Verification of the availability requirement should be completed by the Functional Configuration Audit (FCA), and is a separate -- but related -- issue from the guarantee.

Requirements Guidance:

1. Fill in the required availability. This value should be consistent with the student throughput requirements and operating schedule requirements of the Training System. For non-training applications such as mission rehearsal, this value should reflect the likelihood of successfully completing anticipated mission scenarios; this might require simultaneous availability of several simulators for joint operations -- the availability for a single simulator should be high enough to guarantee the joint availability of the number required for joint operations. As a point of reference -- not a suggested value -- many fielded simulators are demonstrating availabilities better than 0.98.

2. Define availability. Possible definitions are:

a. For normal training applications:
"the ratio '(Time Simulator Is Available For Training) / (Scheduled Time for Training)', where 'Scheduled Time for Training' is reduced by any scheduled training time lost for reasons outside the contractor's control (as determined in concurrence with the government)."

b. For a mission rehearsal simulator:
"the ratio '(Available Dedicated Operating Time) / (Scheduled Dedicated Operating Time)', where 'Scheduled Dedicated Operating Time' is reduced by any scheduled dedicated operating time lost for reasons outside the contractor's control (as determined in concurrence with the government)."

Verification Guidance:

Choose the appropriate paragraph alternative. The first alternative looks at device characteristics and the support system to determine if availability can be met. It strongly -- but implicitly -- relies on the

availability guarantee to assure that the analysis was valid and that availability will be met. The second alternative provides a test, but will often be done before significant deployment and may not be a true predictor of availability in a mature device. The third alternative provides a slightly better test in that it will deal with some actual operational problems. Both the second and third alternatives rely on the availability guarantee to assure continued availability.

3. In blank (3), specify the length of time or number of exercises for verification. It is important to remember that the government must decide whether the requirement is satisfied before FCA.

***Process Guidance:** The contractor must be tasked to provide the simulator availability in a Statement of Work for contractor support.*

EXAMPLES
Example 1. A typical requirement, with verification by simulator operation.

3.2.5 Availability. The simulator availability shall be 0.95. Availability is defined as the ratio "(Time Simulator Is Available For Training) / (Scheduled Time for Training)", where "Scheduled Time for Training" is reduced by any scheduled training time lost for reasons outside the contractor's control (as determined in concurrence with the government).

4.2.1.2.5 Availability. This requirement shall be verified by test. The simulator shall be tested for a two-week (80-hour) operating period, during which time it shall be operated in a manner closely approximating normal use.

Example 2. Another typical requirement, with verification by simulator operation.

3.2.5 Availability. The simulator availability shall be 0.95. Availability is defined as the ratio "(Time Simulator Is Available For Training) / (Scheduled Time for Training)", where "Scheduled Time for Training" is reduced by any scheduled training time lost for reasons outside the contractor's control (as determined in concurrence with the government).

4.2.1.2.5 Availability. This requirement shall be verified by test. The simulator shall be tested for a two-month (320-hour) operating period, during which time it shall be fully utilized by actual using command aircrews.

Example 3. A mission rehearsal requirement.

3.2.5 Availability. The simulator availability shall be 0.98. Availability is defined as the ratio "(Available Dedicated Operating Time) / (Scheduled Dedicated Operating Time)", where "Scheduled Dedicated Operating Time" is reduced by any scheduled dedicated operating time lost for reasons outside the contractor's control (as determined in concurrence with the government).

4.2.1.2.5 Availability. This requirement shall be verified by analysis. Component reliability and maintainability shall be estimated. The logistics system shall be modeled and availability verified.

3.2.6 Environmental Conditions. The simulator shall operate __1__. The simulator shall operate after storage __2__. (3)Temperature within the enclosed __4__ shall be maintained between __5__.

4.2.1.2.6 Verification of Environmental Conditions. This requirement shall be verified by analysis (3) and test. Operating and storage requirements shall be verified by analysis based on component manufacturers' specifications. (3)Temperatures within enclosed areas shall be measured during an extended period of other test activities.

RATIONALE

Many simulators operate in specially designed air conditioned facilities. Commercial off-the-shelf equipment is used without modification. Simulators are moved and stored with great care. Therefore, environmental conditions are not a major factor. It is poor practice to let these values drive design unless there is serious reason. When the simulator operates in an air conditional facility, the tolerance ranges can be reduced if necessary to reduce cost or provide additional performance (they need only be consistent with the range of conditions expected in the facility). In general, the contractor should select the values to go in this paragraph.

Requirements Guidance:

1. Insert the required operating temperature and humidity ranges. Most off-the-shelf equipment will operate at a temperature of 15 to 32 degrees-C (59 to 90 degrees-F) and relative humidity of 40 to 70 percent (non-condensing). If certain components (e.g., hydraulic power supply equipment) need to operate over a larger range, state the range for the exceptional simulator components as well. In cases where the simulator is to be operated in a specially designed facility, a qualitative statement may be sufficient. If the simulator is to be deployed to non-climatically controlled facilities, larger operational temperature or humidity ranges may be needed. Note, however, that extreme limits could require specially designed equipment.

2. Fill in with the required storage temperature and humidity ranges. Most off-the-shelf equipment will meet 0 to 60 degrees-C (32 to 140 degrees-F) and 0 to 90 percent relative humidity (non-condensing). If storage is not a major consideration, a qualitative statement may be sufficient. Note, however, that extreme limits could require specially designed equipment.

3. Use this sentence if the simulator contains enclosed student, instructor, or operator areas.

4. Identify the enclosed areas.

5. Identify the temperature range within the enclosed areas. Usually 18 to 24 degrees-C (64 to 75 degrees-F) are specified; this approximates the MIL-STD-1472 "Summer Comfort Zone" range.

Verification Guidance:

3. Use the remainder of this sentence if the simulator contains enclosed student, instructor, or operator areas.

EXAMPLES
Example 1. A simulator that includes a motion system (PIDS requirement).

3.2.5 Environmental Conditions. The simulator shall operate at temperatures between 15 and 32 degrees-C and relative humidities between 40 and 70 percent (non condensing). The equipment in the hydraulic pump room shall operate at temperatures between 15 and 44 degrees-C and relative humidities between 40 and 70 percent (non condensing). The simulator shall operate after storage at temperatures between 0 and 60 degrees C and relative humidities up to 90 percent (non-condensing). Temperature within the enclosed cockpit shall be maintained between 18 and 24 degrees C.

Example 2. Qualitative statements in a System Specification.

3.2.6 Environmental Conditions The simulator shall operate in existing F-16 simulator facilities. The simulator shall operate after storage in temperature controlled government warehouses. Temperature within the enclosed cockpit shall be maintained between 18 and 24 degrees C.

3.2.7 Transportability. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

(1)Not applicable.

-OR-

The simulator shall be transportable by __2__.

4.2.1.2.7 Verification of Transportability. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by analysis that compares the dimensions of the various simulator pieces with vehicle constraints.

RATIONALE
For large Weapons System Trainers transportability is not an issue. Although they are sometimes moved, a contractor handles all details and arranges them to suit the simulator. The process of testing a simulator at a contractor's plant and then shipping to site assures some transportability. For smaller simulators, such as the F-15/16 Unit Training Device, transportability may be an issue since it would be possible to deploy the simulators with the aircraft.

Requirements Guidance:

1. For large Weapons System Trainers or other simulators that will not be deployed use "Not applicable." Otherwise use the second alternative.

2. Specify the transportation mode(s), e.g., C-141 aircraft, padded van, container ship. If there is no specific user requirement, the simulator contractor should provide the mode(s). If there is a specific requirement, the government should provide it.

Verification Guidance: *Select the alternative to match the requirement.*

Process Guidance: *The contractor should be tasked to deliver the simulator to an operational site. In many cases this eliminates the need for transportability requirements.*

3.3 Design and Construction. Standard industry practices shall be used, except as necessary to meet the requirements of this specification.

4.2.1.3 Verification of Design and Construction. This requirement shall be verified by inspection. The simulator shall be inspected to insure compliance with the manufacturer's standards.

RATIONALE
This requirement assumes contractor logistic support; there is no interface with the Air Force supply system.

3.3.1 Materials. Standard industry practices shall be used, except as necessary to meet other requirements of the specifications.

4.2.1.3.1 Verification of Materials. This requirement shall be verified by analyses and inspections that demonstrate that all materials used in the simulator meet the manufacturer's standards.

RATIONALE
This requirement assumes contractor logistic support; there is no interface with the Air Force supply system.

3.3.2 Electromagnetic Radiation. Electromagnetic radiation, at the simulator operating location(s), shall not prevent the simulator from meeting the requirements of this specification. The simulator shall not interfere with the operation of other electronic equipment at that (those) location(s).

4.2.1.3.2 Verification of Electromagnetic Radiation. This requirement shall be verified by analysis and demonstration. The electromagnetic compatibility of the simulator at each operating location shall be analyzed. The simulator shall also operate successfully at that (those) location(s).

RATIONALE
Electromagnetic radiation has not been a big problem in simulators. Specific design requirements and testing are not usually necessary. The operating environment must be evaluated, however, to assure design is adequate. TEMPEST, which is related to electromagnetic radiation, should be covered under paragraph 3.3.9 "System Security".

3.3.3 Nameplates and Product Markings. A nameplate shall be securely fastened to the simulator. The nameplate shall indicate the (1) manufacturer, nomenclature, and serial number.

4.2.1.3.3 Verification of Nameplates and Product Markings. This requirement shall be verified by inspection.

RATIONALE
This requirement defines specific information that must be provided for a nameplate. It deletes all requirements for military standard markings (previously MIL-STD-12 was applied for abbreviations used, MIL-STD-130 for nameplates and product markings, and MIL-STD-1472 for control panel markings), based on the normal requirements for contractor logistics support.

Requirement Guidance:

1. Tailor the required information as appropriate.

3.3.4 Workmanship. All simulator parts shall be free of burrs, sharp edges, and other visual defects.

4.2.1.3.4 Verification of Workmanship. This requirement shall be verified by inspection of the simulator.

RATIONALE
High quality workmanship is required, but there is no need for detailed standards. A simulator often contains many commercial systems built by different manufacturers. All their standards may not be the same.

3.3.5 Interchangeability. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Not applicable.

-OR-

The following interchangeability requirements apply:
__1__.

4.2.1.3.5 Verification of Interchangeability. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by analysis done in conjunction with normal design reviews.

RATIONALE
Interchangeability is not a major area of concern in most simulators. There may be times when it is desirable; some examples include:

a. Use of the same software load for weapons system trainers and mission rehearsal devices, or the use of the same software load in a weapons system trainer and a cockpit procedures trainer.

b. Use of the same environmental data base for two different simulators.

c. Use of the same hardware components in two different simulators.

Interchangeability will be most desirable among various simulators used in the same training system.

Requirements Guidance: *Select the appropriate lead-in alternative.*

1. If interchangeability is applicable, then fill in blank (1) as appropriate.

Verification Guidance: *Choose the appropriate alternative to match the requirement.*

EXAMPLES
3.3.5 Interchangability. The following interchangeability requirements apply:

a. The software load used in this simulator shall be identical to that used in the Combat Talon II Mission Rehearsal Device.

b. The environmental data bases used in this simulator shall be interchangeable with those used in the C-17 and C-141 Weapons System Trainers.

4.2.1.3.5 Verification of Interchangeability. This requirement shall be verified by analysis done in conjunction with normal design reviews.

3.3.6 Safety. The simulator shall be designed and constructed for safe operation and maintenance. The risks due to human error under routine, non-routine, and emergency conditions shall be minimized. A fail-safe design shall be provided in those areas where failure can cause death, severe injury, severe occupational illness, or major system damage. The simulator and its components shall conform to the safety design criteria of MIL-STD-454 Requirement 1; Air Force Occupational Safety and Health (AFOSH) standards __1__; and National Fire Protection Association (NFPA) standards.

Specific requirements include: __2__.

4.2.1.3.6 Verification of Safety. This requirement shall be verified by the MIL-STD-882 risk assessment procedures and associated mishap and hazardous malfunction analyses and reports.

RATIONALE
System safety requires that hazards be prevented from being designed into the simulator. This may be achieved by thorough system safety analyses, conducted under a system safety program, to identify hazards and to impose design requirements and management controls to prevent mishaps by eliminating hazards or reducing the associated risk to an acceptable level. A tailored MIL-STD-882 is used to task the contractor to establish a system safety program. System safety program objectives include the

documentation and feedback of "significant safety data" to applicable design handbooks and specifications; relevant information must be provided to, and included in, this specification.

Requirements Guidance: *A system safety engineer should be consulted to assist in completing this section.*

This paragraph specifies requirements to preclude or limit hazards to personnel, equipment, or both; these requirements are to be imposed by citing established and recognized standards to the extent practical. (All cited documents must be included in the "Applicable Documents" section of this specification.) This paragraph must also include all health and safety criteria to be applied by the system safety program. These criteria shall include consideration of the toxicological effect and environmental impact of hazardous materials, waste and by-products, ionizing and non-ionizing radiation, and mishap mitigating factors such as escape and fire suppression systems. Those safety characteristics unique to the system that constrain the design due to hazards in assembly, disassembly, test, transport, storage, operation, or maintenance shall be stated when covered neither by standard industrial or service practices nor the system specification.

MIL-STD-454 Requirement 1 provides "Safety Design Criteria - Personnel Hazards" for electronic equipment, and is kept updated on a regular basis; the latest revision of this document should be applied.

1. Place applicable AFOSH standards in blank (2). The following AFOSH standards may be applicable:
127-22 Walking Surfaces, Guarding Floor and Wall Openings and Holes, Fixed Industrial Stairs, and Portable and Fixed Ladders
127-66 General Industrial Operations (Chapter 4)
127-118 Flight Simulator Fire Protection
161-8 Permissible Exposure Limits for Chemical Substances

NOTE: AFOSH Standard 127-118 includes requirements for fire protection, facility emergency lighting, emergency lighting in enclosed areas, a means to disconnect electrical power to the entire training system at all key locations, electrical surge protection, electrical and communications cable and wiring, etc. It is normally mandatory for any training system.

2. In blank (2), add simulator-specific requirements that are not picked up in the generic standards cited above. Select from the following if it applies to the specific simulator.

a. MIL-STD-1472 was applied to acoustical noise limits before it was discontinued; the standard included a convenient reference regarding maximum acceptable levels for both hazardous and non-hazardous noise. The basic requirement for "safe operation and maintenance" should suffice if hazardous noise levels are the only concern. If non-hazardous noise levels are also a concern, add the following (the exception is included to avoid conflict with aural cuing requirements): "Except as required elsewhere in this specification, personnel shall be provided an acoustical environment that will not interfere with voice or any other communications, or cause fatigue."

b. If blank (2) includes AFOSH 127-118, and if this standard still requires that MIL-H-83282 hydraulic fluid to be used (see AFOSH 127-118 paragraph 6.e.(4)), then add the following: "A commercially available hydraulic fluid may be substituted for the MIL-H-83282 hydraulic fluid required by AFOSH Standard 127-118, subject to the approval of the System Safety Representative (the primary concern is that it have a flash point of 380°-F or higher)."

c. If an active control loading system is to be included in the simulator, add the following: "A fail-safe safety system shall be included in the simulator flight control system to reduce the risk of non-simulated erratic control movement."

Verification Guidance: *The system safety program established under MIL-STD-882 includes comprehensive processes for hazard identification and resolution, safety verification, and documentation.*

Process Guidance: *A system safety program should be conducted by the contractor to identify, evaluate, and eliminate (or reduce the associated risk to an acceptable level) system hazards. The system safety program should be mandated by statement of work tasking that invokes application of MIL-STD-882, as tailored for the specific simulator acquisition. The statement of work must define the scope of the system safety program. The statement of work must also assure that necessary changes to the simulator components identified by the system safety program are documented in this specification.*

A system safety engineer and/or system safety manager (SSM) should be available to assist with the statement of work preparation.

EXAMPLES
3.3.6 Safety. The simulator shall be designed and constructed for safe operation and maintenance. The risks due to human error under routine, non-routine, and emergency conditions shall be minimized. A fail-safe design shall be provided in those areas where failure can cause death, severe injury, severe occupational illness, or major system damage. The simulator and its components shall conform to the safety design criteria of MIL-STD-454 Requirement 1; Air Force Occupational Safety and Health (AFOSH) standards 127-22, 127-66 (Chapter 4), 127-118 and 161-8; and National Fire Protection Association (NFPA) standards.

Specific requirements include:

a. Except as required elsewhere in this specification, personnel shall be provided an acoustical environment that will not interfere with voice or any other communications, or cause fatigue.

b. A commercially available hydraulic fluid may be substituted for the MIL-H-83282 hydraulic fluid required by AFOSH Standard 127-118, subject to the approval of the System Safety Representative (the primary concern is that it have a flash point of 380°-F or higher).

c. A fail-safe safety system shall be included in the simulator flight control system to reduce the risk of non-simulated erratic control movement.

3.3.7 Human Engineering. The simulator shall provide a work environment that fosters effective procedures and work patterns, and minimizes factors that degrade human performance or increase occurrences of human error. The following requirements shall apply:

a. Controls, displays, marking, coding, labeling and arrangement schemes shall be uniform for common functions of all equipment. The relationship of any control to its associated display and the display to its associated control shall be apparent and unambiguous.

b. Areas of the simulator (except where required to match the aircraft) shall contain adequate space for personnel, as well as free volume for movements they are required to perform during operation and maintenance tasks under normal and emergency conditions.

c. Controls, displays, and other simulator equipment shall be arranged for efficient operation and maintenance.

d. Displays used for simulation control or maintenance purposes shall provide a clear indication of simulator status under all operating conditions. These displays shall be optimized for the design viewing distance. Information shall be presented in a consistent format. Data shall be readily usable and readable in form so that the user need not transpose, compute, interpolate or mentally translate into other units, numbers, or languages. Information density shall be minimized.

e. The simulator, when installed in the facility, shall be adequately illuminated for performance of operation and maintenance.

f. Labels, legends, placards, signs, markings, or a combination of these shall be provided whenever it is necessary for personnel to identify, interpret, follow procedures, or avoid hazards, except where it is obvious what an item is and what should be done with it.

g. Personnel enclosures shall be adequately ventilated.

h. The simulator's acoustic environment shall not cause fatigue, interfere with voice or other communications, or in any other way degrade system effectiveness.

4.2.1.3.7 Verification of Human Engineering. This requirement shall be verified by analysis and demonstration. The capability and configuration of various components of the simulator shall be analyzed in design reviews.

RATIONALE
This paragraph represents a suggested tailoring of human engineering and computer interface requirements in MIL-STD-1472 and MIL-STD-1801. Quantitative requirements have not been included in order to allow flexibility in choosing commercial components that may not be fully compliant with these standards, although they meet their intent for purposes of this specification. This is especially true for control and display systems.

Requirements Guidance: *Delete or tailor the enumerated items a-h to be consistent with the requirements for this particular application.*

Process Guidance: *There is a large degree of subjectivity associated with this area. If a commercial system has been used and is known to be acceptable, there is little problem. However, when a contractor uses unknown systems or proposes unique designs more care must be taken. Some possible actions:*

a. Require detailed comparisons of control and display systems with the requirements of MIL-STD-1801 as part of a proposal or before government agreement on the display system being used.

b. Rapid prototyping and demonstrations of control and display systems.

c. Demonstrations of other requirements.

d. Mockups.

3.3.8 Nuclear Control. This requirement is not applicable.

4.2.1.3.8 Verification of Nuclear Control. Verification of this requirement is not applicable.

RATIONALE
This requirement is included only to match the outline of MIL-STD-490B. There are no nuclear control requirements in simulators.

3.3.9 System Security.
3.3.9 Prime Item Security. The (1) following vulnerabilities of the simulator shall be minimized (1) with the countermeasures indicated:

__2__. __3__.

The highest level of information processed in the simulator shall be __4__.

4.2.1.3.9 Verification of System Security.
4.2.1.3.9 Verification of Prime Item Security. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The system shall be tested by attempting to exploit each vulnerability and ensuring that the countermeasures provide the required protection.

RATIONALE
The general area of security must deal with system security, TEMPEST, and Communications Security. It must cover both the contractor's plant and the government's operating site.

System security requires that the simulator be protected against such things as theft, damage, destruction, and altering of data. It also requires that classified and other sensitive data be protected from compromise. A System Security Engineering Management (SSEM) Program using MIL-STD-1785 as a guide should be conducted. Security is achieved through a combination of system features, operating procedures, and facility design. Initially, mission critical components and functions (those requiring protection) must be defined. Threats to these functions and components will be defined by considering their vulnerabilities in worst case scenarios over the system life. A working group to brainstorm countermeasures will be assembled, based upon these vulnerabilities. Threats are typically identified by type (e.g., disgruntled employee or spies). The System Security Engineering Manager provides the threat identification and assists with the statement of work.

When the simulator is part of a training system, the SSEM Program will usually be done for the whole training system. This specification should address only the required simulator features. The statement of work must define the scope of the SSEM Program. It should be noted that the simulator must be accredited or certified for use at each of its operating locations.

Some specific items to be addressed in the specification could include:

a. Multilevel security provisions.

b. Provisions for declassifying the simulator.

All features must be integrated with appropriate operating procedures and facility design. There are several common approaches to countermeasures:

a. Dedicated systems - This is the most frequent approach for classified simulators. All persons with access to the simulator must be cleared to the highest level processed and have the need to know. It requires detailed operating procedures and special provisions in the facility to control access. There is often a need associated with dedicated systems to declassify the simulator. In this case there must be specific requirements for removable magnetic storage media, easy removal of classified panels or systems, programs to overwrite memory, etc.

b. Multilevel systems - This type of system is necessary when people with different clearance levels have access to a classified simulator, or when the facility is not rigidly controlled. Multilevel systems build much of the protection into the simulator, and specific specification requirements are necessary. There is no history of the use of such systems in simulators.

Requirements Guidance:

1. If the specific vulnerabilities have not been identified delete the words "following" and "with the countermeasures indicated", and ignore blanks 2 and 3. If this information cannot be determined when the specification is written, then there must be statement of work tasking to update the specification when the information becomes available.

2. List the specific vulnerabilities for which countermeasures are required in the device. If protection is accomplished by procedures or facility design, the vulnerabilities should not be included.

3. List the specific countermeasures to be applied.

4. Fill in with the appropriate classification level. If this information cannot be determined when the specification is written, then there must be statement of work tasking to update the specification when the information becomes available.

Verification Guidance:

Choose the first alternative when all protection will be accomplished with facility features or operating procedures. Otherwise, choose the second alternative.

Process Guidance:

A System Security Engineering Management Program should identify threats and vulnerability. It must also require appropriate contractor interface with the accrediting or certifying authority. It must provide appropriate information for this specification when necessary.

EXAMPLES

Example 1. Assume minimal security data available. In this case the statement of work must task the contractor to update the specification when new information becomes available as a result of the System Security Engineering Management Program. The system specification states:

3.3.9 System Security. The vulnerabilities of the simulator shall be minimized.

Example 2. Once the necessary information becomes available, the complex item requirement specification is updated to state:

3.3.9 Complex Item Security. The following vulnerabilities of the simulator shall be minimized with the countermeasures indicated:

a. Software viruses. A commercially available virus protection program shall be incorporated in the simulator such that all software files are checked on installation.

b. Access to classified data by personnel not cleared to the appropriate level. Use of the system shall require a login password and unique identification with authentication data. The probability of a guess shall be .000001 or less. There shall be no group identifications. A Discretionary Access Control (DAC) system shall insure that classified data is accessed on a need-to-know basis. In addition, the computational system shall be declassified by one: 1) removable hard disc drives, and 2) an overwrite algorithm. The overwrite software shall overwrite the computer memory locations a minimum of three times.

c. Physical damage or destruction. An alarm shall indicate access to the cockpit unless authorized at the instructor console.

d. Access to the KY 601 Panel when the simulator is unattended. The KY 601 Panel shall be easily removable when the simulator is not in use.

The highest level of information processed in the simulator shall be SECRET.

3.3.9.1 TEMPEST. CHOOSE ONE OF THE FOLLOWING ALTERNATIVES:

This requirement is not applicable.

-OR-

The simulator shall be protected against TEMPEST threats.

-OR-

The simulator shall be protected against TEMPEST threats with the following countermeasures. ___1___.

4.2.1.3.9.1 Verification of TEMPEST. CHOOSE ONE OF THE FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test and analysis. Analysis of vendor and component data shall verify that required radiation and conduction levels are achieved. Where no data are available, test shall verify that required radiation and conduction levels are achieved outside the secured simulator area. If the TEMPEST risk is accepted by ___2___, this requirement shall be considered satisfied.

RATIONALE
The general area of security must deal with system security, TEMPEST, and Communications Security. It must cover both the contractor's plant and the government's operating site.

A TEMPEST program should be conducted for all simulators processing classified information. The program should begin by assessing the hazards based on the level of classification, the characteristics of the simulator, and its operating location. Details are found in Air Force Special Security Instructions (AFSSI) 7000 series (most of these documents are classified). When this is accomplished, it will often be found that TEMPEST is not a hazard for many simulators and no-cost TEMPEST control measures will be the only ones necessary. Check with the Communication Computer Security Liaison Office for more details. The next step required is a certification by the MAJCOM and the base that the TEMPEST risk is acceptable. This may involve both analysis and test.

TEMPEST provisions have not been incorporated in most Air Force simulators. The major exception is the shielding of student stations in the Simulator for Electronic Warfare Training in the early 1970s. It was also necessary to replace a computer terminal on the F-16 Operational Flight Trainers due to TEMPEST problems.

Several simulators, or parts of simulators, have been placed in shielded facilities. Operating procedures also affect the TEMPEST hazard. Note however that facility design and development of operating procedures, although integral parts of the development program, should not be covered by this specification.

Requirements Guidance:

Choose the first alternative if the simulator is unclassified or if the all TEMPEST provisions are incorporated in procedures and facility design. Choose the second alternative for classified simulators where the details of the hazard and appropriate countermeasures are not known. The statement of work should task the contractor to update the specification to the first or third alternative when details become available. When the threat and countermeasures are known, use the third alternative.

In blank 1, detail the specific countermeasures included in the simulator.

Verification Guidance:

If the first requirement alternative is chosen, also use the first verification alternative. Otherwise, use the second alternative; indicate the agency that will determine the acceptance of TEMPEST risk in blank 2.

Process Guidance:

The statement of work should task the contractor to do the following in developing a classified simulator:

a. Conduct a TEMPEST analysis or interface with appropriate government agencies to support the analysis.

b. Update this specification as a result of TEMPEST analyses.

c. Perform tradeoffs on TEMPEST countermeasures -- especially trade off the use of TEMPEST certified equipment against protection by facility modification.

EXAMPLES
3.3.9.1 TEMPEST. The simulator shall be protected against TEMPEST threats with the following countermeasures:

a. The four student stations shall be enclosed in a TEMPEST shielded enclosure. The shielding shall attenuate signals originating in the simulator by at least 65 dB in the frequency range 1 to 1000 MHz.

b. The instructor stations shall be arranged to so that they do not face external building walls.

c. The power lines to the facility shall be filtered such that all conducted signals originating in the simulator shall be attenuated by at least 35 dB in the frequency range 0.5 to 500 MHz.

4.2.1.3.9.1 Verification Of TEMPEST. This requirement shall be verified by test and analysis. Analysis of vendor and component data shall verify that required radiation and conduction levels are achieved. Where no data are available, test shall verify that required radiation and conduction levels are achieved outside the secured simulator area. If the TEMPEST risk is accepted by CINCACC, this requirement shall be considered satisfied.

3.3.9.2 Communications Security. CHOOSE ONE OF THE FOLLOWING ALTERNATIVES:

This requirement is not applicable.

-OR-

The classified simulator data transmitted ___1___ shall be protected from compromise by encryption ___2___.

4.2.1.3.9.2 Verification of Communications Security. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by analysis of the encryption device to ensure all classified data can be properly encrypted, transmitted, and decrypted.

RATIONALE
The general area of security must deal with system security, TEMPEST, and Communications Security. It must cover both the contractor's plant and the government's operating site.

Communication security has not been an issue in past simulators because they have been isolated systems. It becomes an issue when:

a. *Simulators are networked, and some portion of the network is not secure.*

b. *The simulator is networked to a Training Management System through a non-secure network.*

Where classified data are transmitted on a non-secure network some encryption will be involved.

Since there is little experience in networking classified simulators, expect extensive tailoring of this requirement. Check with Communication Computer Security Liaison Office for more details.

Requirements Guidance: *Choose the first alternative if no networking is involved or if a special secure network is totally contained within the simulator or a controlled access facility. Otherwise choose the second alternative, and fill in the blanks in accordance with the following guidance:*

1. *Indicate the name of the network.*

2. *Describe the method of encryption.*

Verification Guidance: *Choose the first alternative if no networking is involved or if a special secure network is totally contained within the simulator or a controlled access facility. Otherwise choose the second alternative.*

EXAMPLES
3.3.9.2 Communications Security. Classified simulator data transmitted to the Training Management System on commercial telephone lines shall be protected from compromise by encryption using an STU-3 telephone.

3.4 Computer Resources. All simulator software shall be written in Ada, except for commercial off-the-shelf (COTS) software which includes __1__ and __2__. All simulation software shall be object oriented. The software architecture shall have the following three levels: a) executive level, b) subsystem level, and c) component level. Each subsystem level shall model the systems on the real aircraft, and each component level shall model the components of the aircraft being simulated (e.g., fuel pumps, turbines, servo-valves). The executive level shall coordinate the subsystem level. The subsystem shall manage a group of components at the component level so that they behave as a unit. The component level shall be concerned only with computation. Each subsystem shall have no direct knowledge of other subsystems. All information shall be transferred from the memory locations where each subsystem will place its data. The components shall have no knowledge of the outside world except through input or output

parameters. Any systems outside the aircraft such as radars, missiles, or other aircraft shall also be simulated using structural modeling and object oriented design. Where COTS software (including vendor operating systems and software device drivers) is used, it shall not be modified.

The software shall perform a functional checkout of the trainer hardware interfaces at rates and values characteristic of the mission operation mode. A set of diagnostic computer software shall be provided to isolate equipment failures.

4.2.1.4 Verification of Computer Resources. This requirement shall be verified by analysis and test. The language and architecture requirements shall be verified by review and evaluation of design documentation and analysis of design review presentations. The requirement for diagnostic and test software shall be verified by: a) analysis of its design to ensure all functions are performed, b) by a test of all required functions, and finally c) by analysis of its performance during other testing.

RATIONALE
The government now requires all newly developed software to be written in Ada. The use of COTS software is encouraged, but COTS software should not be modified unless the modifications are written in Ada. The following guidelines for waivers and exceptions to Ada apply:

1) *Desktop computer & workstation software: Not applicable*

2) *100% COTS software: Not applicable*

3) *Application software life less than 3 years: Not applicable*

4) *Newly development with non-Ada language: Waiver required*

5) *Modified COTS software: Waiver required*

6) *Reuse of existing non-Ada code that is modified more than 33%: Waiver required*

7) *Language (including approved HOL) along with Ada: Exception required*

8) *Fourth Generation Languages used to support database language SQL: Exception required*

9) *Fourth Generation Languages used to support rapid prototyping (not fielded): Exception required*

10) *Small projects (under 5000 software lines of code), where Ada is not cost effective or feasible: Exception required.*

For more information, contact that the ASC/EN Computer Resource Focal Point's Office.

This requirement also insures that the software will be developed using structural modeling techniques. The object-oriented design will make the system easier to maintain and modify as training needs change. The requirement for structural modeling shall be mapped to the DOD-STD-2167 software development process; this will require a good deal of effort.

Requirements Guidance: *Fill in blanks as follows:*

1. *List the COTS software used in the simulator.*

2. *List any other exceptions to the use of Ada.*

EXAMPLES

3.4 Computer Resources. All simulator software shall be written in Ada, except for commercial off-the-shelf (COTS) software which includes computer vendor developed software and workstation software. All simulation software shall be object oriented. The software architecture shall have the following three levels: a) executive level, b) subsystem level, and c) component level. Each subsystem level shall model the systems on the real aircraft, and each component level shall model the components of the aircraft being simulated (e.g., fuel pumps, turbines, servo-valves). The executive level shall coordinate the subsystem level. The subsystem shall manage a group of components at the component level so that they behave as a unit. The component level shall be concerned only with computation. Each subsystem shall have no direct knowledge of other subsystems. All information shall be transferred from the memory locations where each subsystem will place its data. The components shall have no knowledge of the outside world except through input or output parameters. Any systems outside the aircraft such as radars, missiles, or other aircraft shall also be simulated using structural modeling and object oriented design. Where COTS software (including vendor operating systems and software device drivers) is used, it shall not be modified.

The software shall perform a functional checkout of the trainer hardware interfaces at rates and values characteristic of the mission operation mode. Any hardware normally connected shall be automatically disconnected. A set of diagnostic computer software shall be provided to isolate equipment failures.

3.4.1 Computer Hardware. An unmodified, commercial off-the-shelf computer hardware system shall be used in the simulator.

4.2.1.4.1 Verification of Computer Hardware. This requirement shall be verified by inspection. Inspection of computer vendor hardware documentation at computer hardware design reviews or other technical evaluations during the design process shall verify the use of unmodified, commercial off-the-shelf computer hardware.

RATIONALE
Use of non-development computer hardware reduces the costs and time associated with developing a simulator, and is consistent with DOD policy.

The past practice of requiring hardware processor independence in order to achieve some level of fault tolerance is not consistent with the modern commercial hardware configurations such as those used in real-time simulators. (Nowadays a computer cabinet will typically include multiple, non-independently operating processors linked via internal busses.) The requirement that "all processors shall be independent of each other to the maximum extent possible within the constraints of unmodified COTS hardware" has therefore been removed from the recommended requirement text.

3.4.2 Flexibility and Expansion. A minimum of __1__ percent of the total memory installed in the simulator shall be spare (i.e., not used for any activity required by this specification and immediately available for growth without any hardware modification or change to the software architecture). The memory shall be expandable __2__ percent of the total installed in the simulator. A minimum of __3__ percent of each second shall be allocated as spare time (i.e., not used for any activity required by this specification and immediately available for growth without any hardware modification or change to the software architecture). This shall apply evenly to each processor.

The following shall apply:

Total Spare Time (TST) = Required Percent Spare Time (RPST)*(1000 ms/sec)

a. A time burner program shall burn (TST/Maximum Iteration Rate(MIR)) ms each 1/MIR interval such that the sum is TST for all intervals.

b. For purely asynchronous systems, a minimum of TST ms shall be burned each second with all events occurring within the Maximum Software Transport Delay (MSTD) allowed by this specification.

c. For systems that are a combination of both synchronous and asynchronous, the above applies with the additional requirement that all events occur within their MSTD.

4.2.1.4.2 Verification of Flexibility and Expansion. This requirement shall be verified by analysis and test. Spare memory and expansion capability shall be analyzed during reviews of computer system documentation and at design reviews. Spare memory shall test at least __4__ times during other verification activities, where the simulator use approximates normal training operation. Each test shall cover at least a one hour period of activity, and shall use an operating system utility to identify the spare memory. Spare time shall be verified by exercising the time burner program at least __5__ times during other verification activities, where the simulator use approximates normal training operation. Each test shall cover at least a one hour period.

RATIONALE
The computational system must be able to grow and expand without degradation of performance as training needs increase and aircraft systems change. Note that the MSTD requirement may be stated specifically or it may need to be derived from other requirements such as fidelity.

Requirements Guidance:

1. Specify the percent of total memory that is available as spare. Fifty percent has typically been required for the older main-frame technology applications. However, modern hardware and software architectures can accommodate growth far better than the older systems. Consider the complexity of the specific application (it always seems to take more than anticipated), but balance the required spare against the required growth capability. Life cycle costs will be reduced if the balance is weighted in favor of growth capability rather than resident spare, since memory will continue to become cheaper as the technology progresses.

2. Specify the percent of memory expansion capability required. One hundred percent growth capability has typically been required for the older main-frame technology applications. However, refer to the comments above and consider trading off resident spare memory for greater growth capability.

3. Specify the percent of total computational time that is available as spare. Fifty percent has typically been required for the older main-frame technology applications. If the architecture will easily accommodate growth in number-crunching capability, the requirement may be backed off somewhat -- but remember that it always takes more time than anticipated.

As a final note to the above guidance, keep in mind that run-time checking requires additional executable code. Resident spare memory and processing time should be sufficient to accommodate run-time checking during software development and integration.

Verification Guidance:

4. Specify the number of tests required. Three should be sufficient.

5. Specify the number of tests required. Three should be sufficient.

EXAMPLES
3.4.2 Flexibility and Expansion. A minimum of 20 percent of the total memory installed in the simulator shall be spare (i.e., not used for any activity required by this specification and immediately available for growth without any hardware modification or change to the software architecture). The memory shall be expandable 400 percent of the total installed in the simulator. A minimum of 40 percent of each second shall be allocated as spare time (i.e., not used for any activity required by this specification and immediately available for growth without any hardware modification or change to the software architecture). This shall apply evenly to each processor.

The following shall apply:

Total Spare Time (TST) = Required Percent Spare Time (RPST)*(1000 ms/sec)

a. A time burner program shall burn (TST/Maximum Iteration Rate(MIR)) ms each 1/MIR interval such that the sum is TST for all intervals.

b. For purely asynchronous systems, a minimum of TST ms shall be burned each second with all events occurring within the Maximum Software Transport Delay (MSTD) allowed by this specification.

c. For systems that are a combination of both synchronous and asynchronous, the above applies with the additional requirement that all events occur within their MSTD.

4.2.1.4.2 Verification of Flexibility and Expansion. This requirement shall be verified by analysis and test. Spare memory and expansion capability shall be analyzed during reviews of computer system documentation and at design reviews. Spare memory shall be tested at least three times during other verification activities, where the simulator use approximates normal training operation. Each test shall cover at least a one hour period of activity, and shall use an operating system utility to identify the spare memory. Spare time shall by verified by exercising the time burner program at least three times during other verification activities, where the simulator use approximates normal training operation. Each test shall cover at least a one hour period.

3.4.3 Software Portability. Not Applicable.

4.2.1.4.3 Verification of Software Portability. Verification of this requirement is not applicable.

RATIONALE
Sufficient software portability is achieved by compliance with other requirements herein.

3.5 Logistics.

4.2.1.5 Verification of Logistics. Verification of this requirement is not applicable.

RATIONALE
This is a title only paragraph.

Requirements Guidance: *Almost all simulators now use contractor support. In such a concept, the system developer is initially responsible for all logistics support necessary to maintain the level of availability required. Where a simulator is part of a larger system, such as a training system, the requirements for logistics support on the larger system will apply. With contractor logistics support, the contractor is responsible (and should be given the flexibility needed) to provide the required availability. Therefore, it is recommended that no detailed logistic requirements be stated in this specification.*

Process Guidance: *Requirements for contractor logistics support are largely procedural (as opposed to simulator design requirements) and should therefore be covered in a Statement of Work.*

3.5.1 Maintenance. The simulator shall meet all requirements of this specification when maintained in accordance with the requirements of __1__.

4.2.1.5.1 Verification of Maintenance. This requirement shall be verified by analysis. If the simulator meets the availability requirements of __2__, the requirement is met. If the simulator fails to meet these requirements, then data shall be analyzed to assure that maintenance is adequate.

RATIONALE

Requirements Guidance: *In blank (1), state where the requirements for contractor maintenance are found.*

Verification Guidance: *In blank (2), state where the requirements for contractor maintenance are found.*

EXAMPLES

3.5.1 Maintenance. The simulator shall meet all requirements of this specification when maintained in accordance with the requirements of the Statement of Work for Contractor Support of the F-15\F-16 Unit Training Devices.

4.2.1.5.1 Verification of Maintenance. This requirement shall be verified by analysis. If the simulator meets the availability requirements of the Statement of Work for Contractor Support of the F-15\F-16 Unit Training Devices, the requirement is met. If the simulator fails to meet these requirements, then data shall be analyzed to assure that maintenance is adequate.

3.5.2 Supply. The simulator shall meet all requirements of this specification when supply is accomplished in accordance with the requirements of ______________.

4.2.1.5.2 Verification of Supply. This requirement shall be verified by analysis. If the simulator meets the availability requirements of________________ the requirement is met. If the simulator fails to meet these requirements then data shall be analyzed to assure that supply is adequate.

RATIONALE

Requirements Guidance: *Fill in the blank stating where the requirements for contractor supply are found.*

Verification Guidance: *Fill in the blank stating where the requirements for contractor supply are found.*

Process Guidance:

EXAMPLES

3.5.2 Supply The simulator shall meet all requirements of this specification when supply is accomplished in accordance with the requirements of the Statement of Work for Contractor Support of the F-15\F-16 Unit Training Devices.

4.2.1.5.2 Verification of Supply This requirement shall be verified by analysis. If the Simulator meets the availability requirements of the Statement of Work for Contractor Support of the F-15\F-16 Unit Training Devices the requirement is met. If the simulator fails to meet these requirements then data shall be analyzed to assure that supply is adequate.

3.6 Personnel and Training.

4.2.1.6 Verification of Personnel and Training. Verification of this requirement is not applicable.

RATIONALE

This is a title only paragraph. Almost all simulators now use contractor support. Many systems also use contractor personnel to operate the device. In such a concept the system developer is initially responsible for all operation and support. This includes providing personnel to operate the simulator, personnel to maintain the simulator, and providing appropriate training for these people. With contractor support it is desirable to force maximum contractor responsibility and allow maximum contractor flexibility to provide the stated availability. Therefore it is recommended that no detailed personnel or training requirements be stated in the specification.

Many part task trainers require operation by the crewmember being trained (i.e. self based instruction) and a few still require Air Force operation. In these cases it is appropriate to state who will operate the devices.

Process Guidance:

3.6.1 Personnel. The simulator shall meet all requirements of this specification when operated ___1___ and maintained by personnel in accordance with the requirements of ___2___.

4.2.1.6.1 Verification of Personnel. This requirement shall be verified by analysis. If the simulator ___3___ meets all other requirements of this specification and of ___4___ then the requirement is met. If the simulator fails to meet these requirements then data shall be analyzed to assure that personnel requirements are met.

RATIONALE
This paragraph provides for contractor maintenance and either contractor or Air Force Operation of the Simulator.

Requirements Guidance: *Fill in the blanks as follows:*

1. Delete if contractor operation is required or fill in the types of personnel who will operate the device.

2. Fill in the blank stating where the requirements for contractor operation (and support) are found.

Verification Guidance: *Fill in the blanks as follows:*

3. Delete if contractor operation is required or fill with "when operated by" the types of personnel who will operate the device.

4. Fill in the blank stating where the requirements for contractor operation (and support) are found.

Process Guidance:

EXAMPLES
3.6.1 Personnel The simulator shall meet all requirements of this specification when operated and maintained by personnel in accordance with the requirements of the Statement of Work for Contractor Support of the F-15 Operational Flight Trainer.

4.2.1.6.1 Verification of Personnel This requirement shall be verified by analysis. If the simulator meets all other requirements of this specification and of the Statement of Work for Contractor Support of the F-15 Operational Flight Trainer then the requirement is met. If the simulator fails to meet these requirements then data shall be analyzed to assure that personnel requirements are met.

3.6.1 Personnel The simulator shall meet all requirements of this specification when operated by the pilots being trained and maintained by personnel in accordance with the requirements of the Statement of Work for Contractor Support of the F-15/F-16 Unit Training Device.

4.2.1.6.1 Verification of Personnel This requirement shall be verified by analysis. If the simulator when operated by the pilots being trained meets all other requirements of this specification and of the Statement of Work for Contractor Support of the F-15 Operational Flight Trainer then the requirement is met. If the simulator fails to meet these requirements then data shall be analyzed to assure that personnel requirements are met.

3.6.2 Training. Not applicable

4.2.1.6.2 Verification of Training. Verification of this requirement is not applicable.

RATIONALE
With contractor operation and maintenance the government should allow the maximum flexibility in obtaining the people to operate and maintain the device. If the government operation is required then some training by the contractor is required but this should be covered by the Statement Of Work.

Process Guidance:

3.7 Major Component Characteristics.

4.2.1.7 Verification of Major Component Characteristics. Verification of this requirement is not applicable.

RATIONALE
This is a title only paragraph.

3.7.1 Synthetic Environment. The synthetic environment shall support simulation of __1__. The environment shall include (2) geographic, geodetic, atmospheric, celestial, and entity information, as defined in the following subparagraphs. The synthetic environment shall interact with the simulated air vehicle and its own various components in accordance with physical laws and design criteria, unless otherwise defined by this specification. The simulator shall operate __3__. (4)Except as otherwise specified, the synthetic environment shall meet all requirements of this specification at every point in this gaming area.

4.2.1.7.1 Verification of Synthetic Environment. This requirement shall be verified by analysis of source data, mathematical models, and architecture during the design process.

RATIONALE
This section of the specification considers the environment as one single, interactive entity. It is intended that the environment interact naturally and completely with the simulated vehicle and its own subcomponents in a manner completely analogous to the real world.

The scope and details of the subparagraphs can be highly influenced by: (1) the nature of the training device involved (e.g., whether a Part Task Trainer, a Weapon System Trainer, or a Mission Rehearsal Device), (2) the nature of the tasks to be trained (e.g., the use of a particular model of weather radar versus the training of all crew members in multiple aircraft in all phases of a mission), (3) the specific type of aircraft and the devices/weapons with which it is equipped, and (4) the user involved, since the nature of missions can vary significantly from user to user.

This section defines the extent of the environment for the particular simulator being procured. It is extremely top level; the gaming area is the total area on the earth's surface over which the simulator can fly. Some information, especially geographic information (permanent features on the earth's surface), requires an extensive simulation database.

The intent of the environment section is to treat the world outside the simulated aircraft as a whole -- rather than dividing it up among simulator systems such as visual, radar, electronic combat, etc. The statement "interact with simulated air vehicle and its own various components in accordance with physical laws" is intended to mean that simulated objects interact as in the real world (i.e., they occult each other and the simulated signals based on geometry, they have a "physical presence" and cannot fly through each other, multiple simulated aircraft in the environment affect simulated ground-based radars, etc.). These details are not specifically spelled out in the specification.

Requirements Guidance:

1. The blank should specify the purpose(s) of the synthetic environment. It should include an entry made up of one or more of the following: out-the-window visual; electro-optical sensor; infrared sensor; radar; LIDAR; electronic combat; celestial navigation; Global Positioning System; navigation; take-off and landing operations, etc.

2. Data types which do not apply to a specific application should be deleted from the requirement.

3. Describe the area of operation.

4. Delete "except as otherwise specified" if the environmental requirements are constant throughout the gaming area.

Process Guidance: *Often the scope and details of many of the subparagraphs are not finalized until after a contract is awarded; often these are later decided by such mechanisms as technical working group meetings, technical interchange meetings, design reviews, or site visits -- all of which involve the contractor, the user, and acquisition representatives. If such is the case, the contractor must be tasked to update this specification with the appropriate information once the details are agreed upon.*

EXAMPLES
Example 1. A typical weapons system trainer. In this case other paragraphs define areas of geographic coverage.

3.7.1 Synthetic Environment. The synthetic environment shall support simulation of out-the-window visual, take-off and landing operations, weather, electro-optical sensor, radar, and electronic combat. The environment shall include geographic, geodetic, atmospheric, celestial, and entity information, as defined in the following subparagraphs. The synthetic environment shall interact with the simulated air vehicle and its own various components in accordance with physical laws and design criteria, unless otherwise defined by this specification. The simulator shall operate worldwide between latitudes 70°N and 70°S. Except as otherwise specified, the synthetic environment shall meet all requirements of this specification at every point in this gaming area.

Example 2. A part-task trainer. All environment requirements apply throughout the gaming area.

3.7.1 Synthetic Environment. The synthetic environment shall support simulation of out-the-window visual, electro-optical sensor, radar, and electronic combat. The environment shall include geographic, geodetic, atmospheric, celestial, and entity information, as defined in the following subparagraphs. The synthetic environment shall interact with the simulated air vehicle and its own various components in accordance with physical laws and design criteria, unless otherwise defined by this specification. The simulator shall operate in a 50000 square mile area surrounding Tucson, Arizona. The synthetic environment shall meet all requirements of this specification at every point in this gaming area.

3.7.1.1 Geographic. The horizontal datum for geographic information shall be the World Geodetic System 84 (WGS 84). The vertical datum shall be Mean Sea Level (MSL). Geographic information shall cover __1__. __2__.

4.2.1.7.1.1 Verification of Geographic. This requirement shall be verified by analysis of the geographic database during the design process.

RATIONALE

This section includes all geographically keyed information, i.e., that which is permanently fixed to a specific location on the earth's surface. Requirements are specified for simulator geographic information as a whole, without reference to specific subsystems (i.e., CIG, DRLMS, etc.). This paragraph specifies the datums and amount of the earth's surface that will be represented in the simulation environment. Of the many geoid models available, WGS 84 is probably the most universal. In certain limited cases, a different model may be specified to give a more accurate data set in a specific area; however, this can severely limit the extent of the geographic information contained in the total environment. A knowledgeable source, such as the Defense Mapping Agency, should be consulted prior to specifying a datum other than WGS 84. The amount of earth surface covered is defined as the area of geographic coverage.

Requirement Guidance:

1. Fill in the geographic area to be covered; use latitudes and longitudes to describe the extent of the simulated geographic environment. In cases wherein the gaming area is irregularly shaped and/or fragmented into a number of discontinuous sections, it is recommended that an annotated map be inserted here to illustrate the extent requirements. Note that there are alternative forms to specifying the area of geographic coverage, such as WAC/WAG cell numbers, TPC/JOG/ONC sheet numbers, aerial photography roll and frame numbers, etc. The use of such alternates may be appropriate to specific applications, but -- to remain as generic as possible in terms of source material -- it is recommended that geodetic coordinates be used in general.

2. Identify any differences in geographic coverage among the visual and various sensor system simulations.

EXAMPLES

Example 1. Desired area of geographic coverage is known.

3.7.1.1 Geographic. The horizontal datum for geographic information shall be the World Geodetic System 84 (WGS 84). The vertical datum shall be Mean Sea Level (MSL). Geographic information shall cover the entire area between 29°04'00"N and 44°32'00"N latitude and 84°30'00"W and 121°15'00"W longitude.

Example 2. Area of geographic coverage is to be determined during development. A process interface is required. Different visual and radar simulation areas are required.

3.7.1.1 Geographic. The horizontal datum for geographic information shall be the World Geodetic System 84 (WGS 84). The vertical datum shall be Mean Sea Level (MSL). Geographic information shall cover a 1,000,000 square nautical mile area in the Continental United States. All of this information shall be used for the radar system simulation. Only a 50,000 square mile area need be used for out the window visual simulation.

3.7.1.1.1 Qualitative Geographic Requirements. SELECT ONE OF THE FOLLOWING REQUIREMENTS

The geographic environment shall replicate (1) the real-world geographic environment in the area of geographic coverage. It shall provide: (2)

a. Actual colors of terrain surfaces and features.

b. Infrared signatures of surfaces and features based on season and time of day.

c. Representations of runway lights, rotating beacons, runway markings, etc.

d. Alignment of roads, streams, railroads and other linear features to produce a continuous appearance. Roads and bridges shall be aligned.

e. Proper alignment and appearance of power lines, including towers and wires.

f. Trafficability of ground vehicles, i.e., the motion and velocity of surface entities shall be based on surface properties.

g. Appearance of single lane and divided highways, including associated markings.

h. Proper radar reflectivity at all aspect angles.

i. Effects of earth's curvature, terrain and features on signal propagation.

j. The appearance of a smooth transition between the areas and fixtures specified in paragraphs 3.7.1.1.2 to 3.7.1.1.6; i.e., there shall be no distinct difference in appearance between the areas.

-OR-

The geographic environment shall partially replicate the (1) real-world geographic environment in the area of geographic coverage. It shall provide: (2)

a. Typical colors of terrain surfaces and features.

b. Typical infrared signatures of surfaces and features.

c. Representations of runway lights, rotating beacons, runway markings, etc.

d. Alignment of roads, streams, railroads and other linear features to produce a continuous appearance. Roads and bridges shall be aligned.

e. Appearance of single lane and divided highways, including associated markings.

f. Typical radar reflectivity at various aspect angles.

h. Effects of earth's curvature and terrain on signal propagation.

i. The appearance of a smooth transition between the areas and fixtures specified in paragraphs 3.7.1.1.2 to 3.7.1.1.6; i.e., there shall be no distinct difference in appearance between the areas.

-OR-

The geographic environment shall approximate the (1) real-world geographic environment in the area of geographic coverage. It shall provide: (2)

a. Typical colors of terrain surfaces and features.

b. Typical infrared signatures of surfaces and features.

c. Representations of runway lights, rotating beacons, runway markings, etc.

d. Typical radar reflectivity at various aspect angles.

e. Effects of earth's curvature and terrain on signal propagation.

4.2.1.7.1.1.1 Verification of Qualitative Geographic Requirements. This requirement shall be verified by a test that checks each attribute by observing it on an appropriate display in at least three different locations in the area of geographic coverage.

RATIONALE
This paragraph provides:

a. An overall qualitative statement for simulation of the geographic environment. The terms replicated, partially replicated, and approximated are intended to imply level of "closeness" to the real world actually required. The distinction between these terms could be somewhat blurry in regard to specifics; however, replicated implies a top-of-the-line simulation as close to the real world as feasible, partially replicated implies less fidelity, and approximated the lowest level of fidelity.

b. A list of specific features that the geographic environment must provide.

c. A place holder for qualitative requirements for level-of-detail of terrain, planimetry, and texture.

The level of fidelity required by the database should be consistent with the type of image generator (visual, radar, or sensor) required. The level of fidelity of these presentations is a major cost driver.

Requirements Guidance:

1. Generally it will be necessary to simulate an area of the real world. However, in some cases, only typical terrain will be desired. In these cases use a different statement such as "typical real-world terrain and features over the area of geographic coverage".

2. Add, delete, or tailor the subparagraphs as required. If details of terrain, planimetry and culture are to be defined later in the program, include statements on the degree-of-fidelity required. In a system specification, once paragraphs 3.7.1.1.2 to 3.7.1.1.6 are completed these statements should be deleted.

EXAMPLES
Example 1. A PIDS for a large complex weapons system trainer.

3.7.1.1.1 Qualitative Geographic Requirements. The geographic environment shall replicate the real-world geographic environment in the area of geographic coverage. It shall provide:

a. Actual colors of terrain surfaces and features.

b. Infrared signatures of surfaces and features based on season and time of day.

c. Representations of runway lights, rotating beacons, runway markings, etc.

d. Alignment of roads, streams, railroads and other linear features to produce a continuous appearance. Roads and bridges shall be aligned.

e. Proper alignment and appearance of power lines, including towers and wires.

f. Appearance of single lane and divided highways, including associated markings.

g. Proper radar reflectivity at all aspect angles.

h. Effects of earth's curvature, terrain and features on signal propagation.

i. The appearance of a smooth transition between the areas and fixtures specified in paragraphs 3.7.1.1.2 to 3.7.1.1.6; i.e., there shall be no distinct difference in appearance between the areas.

Example 2. A system specification for a large complex weapons system trainer. In this case the contractor is tasked to define the level of detail of terrain, planimetry, and texture.

3.7.1.1.1 Qualitative Geographic Requirements. The geographic environment shall replicate the real-world geographic environment in the area of geographic coverage. It shall provide:

a. Actual colors of terrain surfaces and features.

b. Infrared signatures of surfaces and features based on season and time of day.

c. Representations of runway lights, rotating beacons, runway markings, etc.

d. Alignment of roads, streams, railroads and other linear features to produce a continuous appearance. Roads and bridges shall be aligned.

e. Proper alignment and appearance of power lines, including towers and wires.

f. Appearance of single lane and divided highways, including associated markings.

g. Proper radar reflectivity at all aspect angles.

h. Effects of earth's curvature, terrain and features on signal propagation.

i. The appearance of a smooth transition between the areas and fixtures with different levels of detail; i.e., there shall be no distinct difference in appearance between the areas.

j. The terrain and feature models shall support take off and landing, visual navigation, and a Special Operations Forces Mission in a 10 square mile operating area.

Example 3. A lower fidelity simulator with no radar or sensor simulation.

3.7.1.1.1 Qualitative Geographic Requirements. The geographic environment shall partially replicate the real-world geographic environment in the area of geographic coverage. It shall provide:

a. Typical colors of terrain surfaces and features.

b. Representations of runway lights, rotating beacons, runway markings, etc.

c. Alignment of roads, streams, railroads and other linear features to produce a continuous appearance. Roads and bridges shall be aligned.

d. Appearance of single lane and divided highways, including associated markings.

e. The appearance of a smooth transition between the areas and fixtures specified in paragraphs 3.7.1.1.2 to 3.7.1.1.6; i.e., there shall be no distinct difference in appearance between the areas.

Example 4. A low fidelity simulation of the geography such as might be used in an air-to-air part-task trainer.

3.7.1.1.1 Qualitative Geographic Requirements. The geographic environment shall approximate the real-world geographic environment in the area of geographic coverage. It shall provide:

a. Typical colors of terrain surfaces and features.

b. Typical infrared signatures of surfaces and features.

3.7.1.1.2 Topographic. __1__.

4.2.1.7.1.1.2 Verification of Topographic. This requirement shall be verified by inspection (2) and demonstration. Inspection, during the design process, of the geographic data used in the simulator shall ensure that the topographic configuration meets all requirements. (2)A demonstration shall verify that each of the heterogeneous configurations affects simulator systems in accordance with this specification.

RATIONALE

This section describes how the total topographic data set is required to vary in terms of heterogeneity; i.e., it defines how subsections of the overall area of geographic coverage are to be organized, such that areas of higher data content correspond to areas of greatest training interest. It is here that "Fixtures" -- airfields, corridors, waypoints, etc. -- are initially identified. The topographic configuration may be different from the planimetric configuration. The requirements associated with each of these fixtures are then specified in the remainder of this section.

Requirements Guidance:

1. In blank (1), describe the required topographic data organization.

If topographic requirements are homogeneous insert, "The topographic background area shall consist of the entire area of geographic coverage." In this case paragraphs 3.7.1.1.2.2 to 3.7.1.1.2.5 should be deleted.

Level C and D airplane and helicopter simulators require a minimum of three different airfields. Level D airplane and helicopter simulators additionally require the portrayal of topographic characteristics known to cause landing illusions such as landing approaches over water, uphill or downhill landing areas, rising terrain on the approach path, and unique topographic features. Although a minimum number of airfields are not explicitly stated for lower level simulators, at least one specific airfield is required.

Verification Guidance:

2. Delete "and demonstration" and the last sentence, if the area of geographic coverage is homogeneous.

EXAMPLES

Example 1. A complex Weapon System Trainer PIDS.

3.7.1.1.2 Topographic. The topographic configuration shall be as follows:

a. Topographic proximity-significant fixtures shall include two 100 nautical mile wide corridors. The first shall be centered on, and run the entire north-south length of, the gaming area. The Second shall be centered on a diagonal line running from 27°00'00"N 84°00'00"W to 35°00'00"N 102°00'00"W.

b. Topographic navigation-significant fixtures consist of one nautical mile radius circles about each of the following points: 28°15'15"N 85°50'05"W, 29°00'00"N 86°14'30"W, 30°12'45"N 86°12'25"W, 36°12'24"N 88°24'35"W, 39°00'00"N 100°05'15"W, 32°23'45"N 92°00'00"W, 33°13'35"N 98°21'32"W and 34°14'57"N 101°34'45"W.

c. A single topographic mission-significant fixture shall consist of a five nautical mile radius circle centered at 32°37'45"N 100°15'35"W.

d. Topographic simulation-significant fixtures shall consist of the airfields and immediate surrounding areas at Podunk AL, Peanuts GA, World's End TN, and Big Rock AK.

e. The topographic background area shall consist of all the remaining area of geographic coverage.

Example 2. A system specification for a Level D simulator where areas of high detail must be defined during the program. In this case a process to identify details is necessary.

3.7.1.1.2 Topographic. The topographic configuration shall be as follows:

a. Topographic proximity-significant fixtures shall include two 100 nautical miles wide by 500 nautical miles long corridors within the area of geographic coverage.

b. One hundred topographic navigation-significant fixtures consisting of one nautical mile radius circles within the area of geographic coverage.

c. A single topographic mission-significant fixture shall consist of a 10 nautical mile radius circle within the area of geographic coverage.

d. Topographic simulation-significant fixtures of nine airfields within the area of geographic coverage. The set of airfields shall include topographic characteristics known to cause landing illusions such as landing approaches over water, uphill or downhill landing areas, rising terrain on the approach path, and unique topographic features.

e. The topographic background area shall consist of all the remaining area of geographic coverage.

Example 3. Only uniform coverage is required. Note that in this case paragraphs 3.7.1.1.2.2 to 3.7.1.1.2.5 should be deleted.

3.7.1.1.2 Topographic. The topographic background area shall consist of the entire area of geographic coverage.

3.7.1.1.2.1 Topographic Background Area. The horizontal spacing of terrain elevation posts shall be __1__. The terrain at each elevation post shall be represented to a precision of __2__. The horizontal location of an elevation value shall be within __3__ of the corresponding value as recorded on the source material. The elevation of a point shall be within __4__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.1 Verification of Topographic Background Area. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select __5__ points in the topographic background area that correspond to points of known elevation in the

source data. The program shall then verify that a point of equal altitude occurs within __1__ of the selected point. A computer program to test vertical tenability shall randomly select __6__ points in the topographic background area and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __2__. In addition, __7__ points shall be selected and terrain height measured manually using __8__.

RATIONALE

This paragraph defines the minimum requirements for topographic information across the entire area for which geographic information is defined. Specification sections that follow will put more stringent requirements on subsets of the overall area, but in no case will they be less stringent than the background requirements. If the topographic requirements are homogeneous, paragraphs 3.7.1.1.2.2 to 3.7.1.1.2.5 should be deleted.

Requirements Guidance:

1. *Specify the spacing.*

2. *Specify the quantum in which terrain elevation values will be represented, typically one meter.*

3. *Specify the horizontal tenability value.*

4. *Specify the vertical tenability value.*

Verification Guidance:

5. *Specify the number of points to be tested in the horizontal tenability test.*

6. *Specify the number of points to be tested in the vertical tenability test.*

7. *Specify the number of points to be tested manually.*

8. *Specify a method of test using the simulator systems, e.g., using "the radar altimeter to measure height above terrain, subtracting this height from the aircraft altitude, and verifying that the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."*

NOTE: The term tenability is the absolute accuracy required of the topographic data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES

3.7.1.1.2.1 Topographic Background Area. The horizontal spacing of terrain elevation posts shall be 3 arc-seconds. The terrain at each elevation post shall be represented to a precision of 0.3 meters. The horizontal location of an elevation value shall be within 0.5 arc-seconds of the corresponding value as recorded on the source material. The elevation of a point shall be within 100 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.1 Verification of Topographic Background Area. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select 5000 points in the topographic background area that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within 0.5 arc seconds of the latitude and longitude of the selected point. A computer program to test vertical tenability shall randomly select 5000 points in the topographic background area and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations

of the points agree within 100 meters. In addition, 20 points shall be selected and terrain height measured manually using the aircraft radar altimeter and comparing the results with source data.

3.7.1.1.2.2 Topographic Proximity-significant Fixtures. The horizontal spacing of terrain elevation posts shall be __1__. The terrain at each elevation post shall be represented to a precision of __2__. The horizontal location of an elevation value shall be within __3__ of the corresponding value as recorded on the source material. The elevation of a point shall be within __4__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.2 Verification of Topographic Proximity-significant Fixtures. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select __5__ points in (each/the) topographic proximity-significant feature that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within __1__ of the selected point. A computer program to test vertical tenability shall randomly select __ 6__ points in (each/the) topographic proximity-significant fixture and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __2__. In addition, __7__ points shall be selected and terrain height measured manually using __8__.

RATIONALE
This paragraph defines the requirements for those fixtures within the overall environment for which special requirements exist in proximity to nominal aircraft flight paths; for example, corridors might be proximity-significant fixtures.

Requirements Guidance:

1. *Specify the spacing.*

2. *Specify the quantum in which terrain elevation values will be represented, typically one meter.*

3. *Specify the horizontal tenability value.*

4. *Specify the vertical tenability value.*

Verification Guidance:

5. *Specify the number of points to be tested in the horizontal tenability test.*

6. *Specify the number of points to be tested in the vertical tenability test.*

7. *Specify the number of points to be tested manually.*

8. *Specify a method of test using the simulator systems, e.g., using "the radar altimeter to measure height above terrain, subtracting this height from the aircraft altitude, and verifying that the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."*

EXAMPLES
3.7.1.1.2.2 Topographic Proximity-significant Fixtures. The horizontal spacing of terrain elevation posts shall be 1 arc-second. The terrain at each elevation post shall be represented to a precision of 0.3 meters. The horizontal location of an elevation value shall be within 0.1 arc-seconds of the corresponding value as recorded on the source material. The elevation of a point shall be within 25 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.2 Verification of Topographic Proximity-significant Fixtures. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select 25 points in each topographic proximity-significant feature that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within 0.1 arc seconds of the latitude and longitude of the selected point. A computer program to test vertical tenability shall randomly select 20 points in each topographic proximity-significant fixture and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 25 meters. In addition, 10 points shall be selected and terrain height measured manually using radar altimeter and comparing the results with source data.

3.7.1.1.2.3 Topographic Navigation-significant Fixtures. The horizontal spacing of terrain elevation posts shall be __1__. The terrain at each elevation post shall be represented to a precision of __2__. The horizontal location of an elevation value shall be within __3__ of the corresponding value as recorded on the source material. The elevation of a point shall be within __4__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.3 Verification of Topographic Navigation-significant Fixtures. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select __5__ points in (each/the) topographic navigation-significant feature that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within __1__ of the selected point. A computer program to test vertical tenability shall randomly select __ 6__ points in (each/the) topographic navigation-significant fixture and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __2__. In addition, __7__ points shall be selected and terrain height measured manually using __8__.

RATIONALE
This paragraph defines those fixtures for which special requirements exist due to the particularly stringent metrics associated with navigation, but not necessarily in proximity to nominal aircraft flight paths. Radar offset aimpoints are typical of this class; while distant, they require special treatment in the environment definition.

Requirements Guidance:

1. *Specify the spacing.*
2. *Specify the quantum in which terrain elevation values will be represented, typically one meter.*
3. *Specify the horizontal tenability value.*
4. *Specify the vertical tenability value.*

Verification Guidance:

5. *Specify the number of points to be tested in the horizontal tenability test.*
6. *Specify the number of points to be tested in the vertical tenability test.*
7. *Specify the number of points to be tested manually.*

8. Specify a method of test using the simulator systems, e.g., using "the radar altimeter to measure height above terrain, subtracting this height from the aircraft altitude, and verifying that the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."

NOTE: The term tenability is the absolute accuracy required of the topographic data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES
3.7.1.1.2.3 Topographic Navigation-significant Fixtures. The horizontal spacing of terrain elevation posts shall be 1 arc-second. The terrain at each elevation post shall be represented to a precision of 0.3 meters. The horizontal location of an elevation value shall be within 0.1 arc-second of the corresponding value as recorded on the source material. The elevation of a point shall be within 25 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.3 Verification of Topographic Navigation-significant Fixtures. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select 5 points in each topographic navigation-significant feature that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within 0.1 arc seconds of the latitude and longitude of the selected point. A computer program to test vertical tenability shall randomly select 5 points in each topographic navigation-significant fixture and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 25 meters. In addition, 10 points shall be selected and terrain height measured manually using radar altimeter and comparing the results with source data.

3.7.1.1.2.4 Topographic Mission-significant Fixtures. The horizontal spacing of terrain elevation posts shall be __1__. The terrain at each elevation post shall be represented to a precision of __2__. The horizontal location of an elevation value shall be within __3__ of the corresponding value as recorded on the source material. The elevation of a point shall be within __4__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.4 Verification of Topographic Mission-significant Fixtures. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select __5__ points in (each/the) topographic mission-significant feature that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within __1__ of the selected point. A computer program to test vertical tenability shall randomly select __ 6__ points in (each/the) topographic mission-significant fixture and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __2__. In addition, __7__ points shall be selected and terrain height measured manually using __8__.

RATIONALE
This paragraph defines those fixtures for which special requirements exist as a result of their being targets or other high-interest, mission-specific locations. This class of fixtures has been defined in the event that the normal "proximity-significant" class is inadequate for certain situations; otherwise, this class may be unnecessary.

Requirements Guidance:

1. Specify the spacing.

2. Specify the quantum in which terrain elevation values will be represented, typically one meter.

3. Specify the horizontal tenability value.

4. Specify the vertical tenability value.

Verification Guidance:

5. Specify the number of points to be tested in the horizontal tenability test.

6. Specify the number of points to be tested in the vertical tenability test.

7. Specify the number of points to be tested manually.

8. Specify a method of test using the simulator systems, e.g., using "the radar altimeter to measure height above terrain, subtracting this height from the aircraft altitude, and verifying that the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."

NOTE: The term tenability is the absolute accuracy required of the topographic data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES
3.7.1.1.2.4 Topographic Mission-significant Fixtures. The horizontal spacing of terrain elevation posts shall be 25 meters. The terrain at each elevation post shall be represented to precision of 0.15 meters. The horizontal location of an elevation value shall be within 5 meters of the corresponding value as recorded on the source material. The elevation of a point shall be within 5 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.4 Verification of Topographic Mission-significant Fixtures. This requirement shall be verified by inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select 100 points in the topographic mission-significant feature that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within 5 meters of the selected point. A computer program to test vertical tenability shall randomly select 100 points in the topographic mission-significant fixture and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 5 meters. In addition, 5 points shall be selected and terrain height measured manually using radar altimeter and comparing the results with source data.

3.7.1.1.2.5 Topographic Simulation-significant Fixtures. __1__. The horizontal spacing of terrain elevation posts shall be __2__. The terrain at each elevation post shall be represented to a precision of __3__. The horizontal location of an elevation value shall be within __4__ of the corresponding value as recorded on the source material. The elevation of a point shall be within __5__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.5 Verification of Topographic Simulation-significant Fixtures. This requirement shall be verified by demonstration, inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select __6__ points in (each/the) topographic simulation-significant fixture that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within __2__ of the selected point. A computer program to test vertical tenability shall randomly select __7__ points in (each/the) topographic mission-significant fixture and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __3__. In addition, __8__ points shall be selected and

terrain height measured manually using __9__. The requirement to __10__ shall be verified by demonstration. __11__.

RATIONALE

This paragraph describes fixtures for which special requirements exist as a result of the nature of the simulation itself. For example, "landable" airfields will be identified here since -- unlike other terrain features -- contact with them by the simulated aircraft will not generate a crash condition.

Requirements Guidance:

1. *Describe the unique properties of simulation-significant features, e.g., landable airfields.*

2. *Specify the spacing.*

3. *Specify the quantum in which terrain elevation values will be represented, typically one meter.*

4. *Specify the horizontal tenability value.*

5. *Specify the vertical tenability value.*

Verification Guidance:

6. *Specify the number of points to be tested in the horizontal tenability test.*

7. *Specify the number of points to be tested in the vertical tenability test.*

8. *Specify the number of points to be tested manually.*

9. *Specify a method of test using the simulator systems, e.g., using "the radar altimeter to measure height above terrain, subtracting this height from the aircraft altitude, and verifying that the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."*

10. *Re-identify the simulation-significant feature requirement per 1 above.*

11. *Describe how the demonstration should be conducted if necessary.*

NOTE: The term tenability is the absolute accuracy required of the topographic data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES

3.7.1.1.2.5 Topographic Simulation-significant Fixtures. The airfields specified in paragraph 3.7.1.1.2 constitute the airfields at which simulated landings can occur. The horizontal spacing of terrain elevation posts shall be 100 meters. The terrain at each elevation post shall be represented to a precision of 0.03 meters. The horizontal location of an elevation value shall be within 1 meter of the corresponding value as recorded on the source material. The elevation of a point shall be within 0.03 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.2.5 Verification of Topographic Simulation-significant Fixtures. This requirement shall be verified by demonstration, inspection and test. The spacing and precision of terrain elevation posts shall be verified by inspection of the data used in the simulator. A computer program to test horizontal tenability shall randomly select 20 points in each topographic simulation-significant fixture that correspond to points of known elevation in the source data. The program shall then verify that a point of equal altitude occurs within 1 meter of the selected point. A computer program to test vertical tenability shall randomly select 25 points in each topographic mission-significant fixture and compare the elevation of

these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 0.03 meters. In addition, terrain height shall be measured manually at each airfield specified in paragraph 3.7.1.1.2 by landing the simulated aircraft, reading the simulated altimeter, and comparing with the source data.

3.7.1.1.3 Planimetric. __1__.

4.2.1.7.1.1.3 Verification of Planimetric. This requirement shall be verified by inspection (2) and demonstration. Inspection, during the design process, of the geographic data used in the simulator shall ensure that the planimetric configuration meets all requirements. (2)A demonstration shall verify that each of the heterogeneous configurations affects simulator systems in accordance with this specification.

RATIONALE
This section specifies requirements for natural and cultural feature information. This paragraph describes how the total planimetric data set is required to vary in terms of heterogeneity; i.e., it defines how subsections of the overall area of geographic coverage are to be organized, such that areas of higher data content correspond to areas of greatest training interest. It is here that "Fixtures" -- airfields, corridors, waypoints, etc. -- are initially identified. The planimetric configuration may be different from the topographic configuration. The requirements associated with each of these fixtures are then specified in the remainder of this section.

Requirements Guidance:

1. In blank (1), describe the planimetric data organization.

If planimetric requirements are homogeneous insert, "The planimetric background area shall consist of the entire area of geographic coverage." In this case paragraphs 3.7.1.1.3.2 to 3.7.1.1.3.5 should be deleted.

Level C and D airplane and helicopter simulators require a minimum of three different airfields. Level D airplane and helicopter simulators additionally require the portrayal of planimetric characteristics known to cause landing illusions such as short runways. Although a minimum number of airfields are not explicitly stated for lower level simulators, at least one specific airfield is required.

Verification Guidance:

2. Delete "and demonstration" and the last sentence, if the area of geographic coverage is homogeneous.

EXAMPLES
Example 1. A complex Weapon System Trainer PIDS.

3.7.1.1.3 Planimetric. The planimetric configuration shall be as follows:

a. Planimetric proximity-significant fixtures shall include two 100 nautical mile wide corridors. The first shall be centered on, and run the entire north-south length of, the gaming area. The Second shall be centered on a diagonal line running from 27°00'00"N 84°00'00"W to 35°00'00"N 102°00'00"W.

b. Planimetric navigation-significant fixtures consist of one nautical mile radius circles about each of the following points: 28°15'15"N 85°50'05"W, 29°00'00"N 86°14'30"W, 30°12'45"N 86°12'25"W, 36°12'24"N 88°24'35"W, 39°00'00"N 100°05'15"W, 32°23'45"N 92°00'00"W, 33°13'35"N 98°21'32"W and 34°14'57"N 101°34'45"W.

c. Planimetric mission-significant fixtures shall consist of a five nautical mile radius circle centered at 29°56'47"N 100°15'35"W, a three nautical mile radius circle centered at 32°37'45"N 100°15'35"W, and a ten nautical mile circle centered at 31°35'56"N 98°15'15"W.

d. Planimetric simulation-significant fixtures shall consist of the airfields and immediate surrounding areas at Podunk AL, Peanuts GA, World's End TN, and Big Rock AK.

e. The planimetric background area shall consist of all the remaining area of geographic coverage.

Example 2. A system specification for a Level D simulator where areas of high detail must be defined during the program. In this case a process to identify details is necessary.

3.7.1.1.3 Planimetric. The planimetric configuration shall be as follows:

a. Planimetric proximity-significant fixtures shall include two 100 nautical miles wide by 500 nautical mile long corridors within the area of geographic coverage.

b. One hundred planimetric navigation-significant fixtures consisting of one nautical mile radius circles within the area of geographic coverage.

c. A single planimetric mission-significant fixture shall consist of a 10 nautical mile radius circle within the area of geographic coverage.

d. Planimetric simulation-significant fixtures of nine airfields within the area of geographic coverage. The set of airfields shall include planimetric characteristics known to cause landing illusions such as short runways.

e. The planimetric background area shall consist of all the remaining area of geographic coverage.

Example 3. Only uniform coverage is required. Note that in this case paragraphs 3.7.1.1.3.2 to 3.7.1.1.3.5 should be deleted.

3.7.1.1.3 Planimetric. The planimetric background area shall consist of the entire area of geographic coverage.

3.7.1.1.3.1 Planimetric Background Area. The feature density shall be not less than __1__ three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of __2__. The location of each feature shall be represented to a precision of __3__. The horizontal location of a feature shall be within __4__ arc-seconds of the corresponding value as recorded on the source material. The elevation of a feature shall be within __5__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.1 Verification of Planimetric Background Area. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select __6__ points on features or feature boundaries in the planimetric background area. The program shall then verify location of each point is within __4__ of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select __7__ points within features in the planimetric background area and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __5__. In addition __8__ points shall be selected and locations measured manually using __9__.

RATIONALE

This paragraph defines the minimum requirements for planimetric information across the entire area for which geographic information is defined. Specification sections to follow will put more stringent requirements on subsets of the overall area, but in no case will they be less stringent than the background requirements. If the planimetry requirements are homogeneous, paragraphs 3.7.1.1.3.2 to 3.7.1.1.3.5 should be deleted.

Requirements Guidance:

1. *Specify the density.*

2. *Specify the quantum in which feature elevation values will be represented.*

3. *Specify the quantum in which feature location values will be represented.*

4. *Specify the horizontal tenability value.*

5. *Specify the vertical tenability value.*

Verification Guidance:

6. *Specify the number of points to be tested in the horizontal tenability test.*

7. *Specify the number of points to be tested in the vertical tenability test.*

8. *Specify the number of points to be tested manually.*

9. *Specify a method of test using the simulator systems, e.g., using "the radar cursors to measure locations of features and points on features based on a known position of the simulated aircraft, and verify the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."*

NOTE: The term tenability is the absolute accuracy required of the planimetry data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES
3.7.1.1.3.1 Planimetric Background Area. The feature density shall be not less than 5 three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of 0.3 meters. The location of each feature shall be represented to a precision of 1 meter. The horizontal location of a feature shall be within 1 arc-seconds of the corresponding value as recorded on the source material. The elevation of a feature shall be within 150 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.1 Verification of Planimetric Background Area. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select 1000 points on features or feature boundaries in the planimetric background area. The program shall then verify location of each point is within 1 arc second of latitude and longitude of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select 1000 points within features in the planimetric background area and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 150 meters. In addition 20 points shall be selected and locations measured manually using the radar cursors and comparing results with source data.

3.7.1.1.3.2 Planimetry Proximity-significant Fixtures. The feature density shall be not less than __1__ three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of __2__. The location of each feature shall be represented to a precision of __3__. The horizontal location of a feature shall be within __4__ of the corresponding value as recorded on the source material. The elevation of a feature shall be within __5__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.2 Verification of Planimetry Proximity-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select __6__ points on features or feature boundaries in the planimetric proximity-significant fixtures. The program shall then verify location of each point is within __4__ of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select __7__ points within features in the planimetric proximity-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __5__. In addition __8__ points shall be selected and locations measured manually using __9__.

RATIONALE
This paragraph defines the requirements for those fixtures within the overall environment for which special requirements exist in proximity to nominal aircraft flight paths; for example, corridors might be proximity-significant fixtures.

Requirements Guidance:

1. *Specify the density.*
2. *Specify the quantum in which feature elevation values will be represented.*
3. *Specify the quantum in which feature location values will be represented.*
4. *Specify the horizontal tenability value.*
5. *Specify the vertical tenability value.*

Verification Guidance:

6. *Specify the number of points to be tested in the horizontal tenability test.*
7. *Specify the number of points to be tested in the vertical tenability test.*
8. *Specify the number of points to be tested manually.*
9. *Specify a method of test using the simulator systems, e.g., using "the radar cursors to measure locations of features and points on features based on a known position of the simulated aircraft, and verify the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."*

NOTE: The term tenability is the absolute accuracy required of the planimetry data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES
3.7.1.1.3.2 Planimetry Proximity-significant Fixtures. The feature density shall be not less than 500 three-dimensional features per square kilometer. The elevation of each feature shall be represented to a

precision of 0.3 meters. The location of each feature shall be represented to a precision of 0.5 meters. The horizontal location of a feature shall be within 1000 meters of the corresponding value as recorded on the source material. The elevation of a feature shall be within 5 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.2 Verification of Planimetry Proximity-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select 100 points on features or feature boundaries in the planimetric proximity-significant fixtures. The program shall then verify location of each point is within 1000 meters of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select 100 points within features in the planimetric proximity-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 5 meters. In addition 10 points shall be selected and locations measured manually using the radar cursors and comparing results with source data.

3.7.1.1.3.3 Planimetry Navigation-significant Fixtures. The feature density shall be not less than __1__ three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of __2__. The location of each feature shall be represented to a precision of __3__. The horizontal location of a feature shall be within __4__ of the corresponding value as recorded on the source material. The elevation of a feature shall be within __5__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.3 Verification of Planimetry Navigation-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select __6__ points on features or feature boundaries in the planimetric navigation-significant fixtures. The program shall then verify location of each point is within __4__ of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select __7__ points within features in the planimetric navigation-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __5__. In addition __8__ points shall be selected and locations measured manually using __9__.

RATIONALE
This paragraph defines those fixtures for which special requirements exist due to the particularly stringent metrics associated with navigation, but not necessarily in proximity to nominal aircraft flight paths. Radar offset aimpoints are typical of this class; while distant, they require special treatment in the environment definition.

Requirements Guidance:

1. *Specify the density.*
2. *Specify the quantum in which feature elevation values will be represented.*
3. *Specify the quantum in which feature location values will be represented.*
4. *Specify the horizontal tenability value.*
5. *Specify the vertical tenability value.*

Verification Guidance:

6. Specify the number of points to be tested in the horizontal tenability test.

7. Specify the number of points to be tested in the vertical tenability test.

8. Specify the number of points to be tested manually.

9. Specify a method of test using the simulator systems, e.g., using "the radar cursors to measure locations of features and points on features based on a known position of the simulated aircraft, and verify the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."

NOTE: The term tenability is the absolute accuracy required of the planimetry data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES
3.7.1.1.3.3 Planimetry Navigation-significant Fixtures. The feature density shall be not less than 400 three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of 100 meters. The location of each feature shall be represented to a precision of 0.05 meters. The horizontal location of a feature shall be within 100 meters of the corresponding value as recorded on the source material. The elevation of a feature shall be within 10 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.3 Verification of Planimetry Navigation-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select 100 points on features or feature boundaries in the planimetric navigation-significant fixtures. The program shall then verify location of each point is within 100 meters of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select 100 points within features in the planimetric navigation-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 10 meters. In addition 5 points shall be selected and locations measured manually using the laser range finder, computing position, and comparing to source data.

3.7.1.1.3.4 Planimetry Mission-significant Fixtures. The feature density shall be not less than __1__ three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of __2__. The location of each feature shall be represented to a precision of __3__. The horizontal location of a feature shall be within __4__ of the corresponding value as recorded on the source material. The elevation of a feature shall be within __5__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.4 Verification of Planimetry Mission-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select __6__ points on features or feature boundaries in the planimetric mission-significant fixtures. The program shall then verify location of each point is within __4__ of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select __7__ points within features in the planimetric mission-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __5__. In addition __8__ points shall be selected and locations measured manually using __9__.

RATIONALE

This paragraph defines those fixtures for which special requirements exist as a result of their being targets or other high-interest, mission-specific locations. This class of fixtures has been defined in the event that the normal "proximity-significant" class is inadequate for certain situations; otherwise, this class may be unnecessary.

Requirements Guidance:

1. *Specify the density.*

2. *Specify the quantum in which feature elevation values will be represented.*

3. *Specify the quantum in which feature location values will be represented.*

4. *Specify the horizontal tenability value.*

5. *Specify the vertical tenability value.*

Verification Guidance:

6. *Specify the number of points to be tested in the horizontal tenability test.*

7. *Specify the number of points to be tested in the vertical tenability test.*

8. *Specify the number of points to be tested manually.*

9. *Specify a method of test using the simulator systems, e.g., using "the radar cursors to measure locations of features and points on features based on a known position of the simulated aircraft, and verify the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."*

NOTE: The term tenability is the absolute accuracy required of the planimetry data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES
3.7.1.1.3.4 Planimetry Mission-significant Fixtures. The feature density shall be not less than 500 three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of 1 foot. The location of each feature shall be represented to a precision of 1 foot. The horizontal location of a feature shall be within 10 meters of the corresponding value as recorded on the source material. The elevation of a feature shall be within 10 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.4 Verification of Planimetry Mission-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select 50 points on features or feature boundaries in the planimetric mission-significant fixtures. The program shall then verify location of each point is within 10 meters of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select 25 points within features in the planimetric mission-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 10 meters. In addition 5 points shall be selected and locations measured manually using the laser range finder, computing position, and comparing to source data.

3.7.1.1.3.5 Planimetry Simulation-significant Fixtures. __1__. The feature density shall be not less than __2__ three-dimensional features per square kilometer. The elevation of each feature shall be

represented to a precision of __3__. The location of each feature shall be represented to a precision of __4__. The horizontal location of a feature shall be within __5__ of the corresponding value as recorded on the source material. The elevation of a feature shall be within __6__ of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.5 Verification of Planimetry Simulation-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select __7__ points on features or feature boundaries in the planimetric simulation-significant fixtures. The program shall then verify location of each point is within __5__ of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select __8__ points within features in the planimetric simulation-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within __6__. In addition __9__ points shall be selected and locations measured manually using __10__. The requirement to __11__ shall be verified by demonstration. __12__.

RATIONALE

This paragraph describes fixtures for which special requirements exist as a result of the nature of the simulation itself. For example, "landable" airfields will be identified here since -- unlike other terrain features -- contact with them by the simulated aircraft will not generate a crash condition.

Requirements Guidance:

1. *Describe the unique properties of simulation-significant features, e.g., landable airfields.*

2. *Specify the density.*

3. *Specify the quantum in which feature elevation values will be represented.*

4. *Specify the quantum in which feature location values will be represented.*

5. *Specify the horizontal tenability value.*

6. *Specify the vertical tenability value.*

Verification Guidance:

7. *Specify the number of points to be tested in the horizontal tenability test.*

8. *Specify the number of points to be tested in the vertical tenability test.*

9. *Specify the number of points to be tested manually.*

10. *Specify a method of test using the simulator systems, e.g., using "the radar cursors to measure locations of features and points on features based on a known position of the simulated aircraft, and verifying that the result matches the source data within tolerances required by this specification. Both the vertical tenability and radar altimeter tolerances shall be considered."*

11. *Re-identify the simulation-significant feature requirement per 1 above.*

12. *Describe how the demonstration should be conducted if necessary.*

NOTE: The term tenability is the absolute accuracy required of the planimetry data, both horizontal and vertical, with respect to the datums identified.

EXAMPLES
3.7.1.1.3.5 Planimetry Simulation-significant Fixtures. The airfields specified in paragraph 3.7.1.1.2 constitute the airfields at which simulated landings can occur. The feature density shall be not less than 500 three-dimensional features per square kilometer. The elevation of each feature shall be represented to a precision of 0.015 meters. The location of each feature shall be represented to a precision of 0.015 meters. The horizontal location of a feature shall be within 1 meter of the corresponding value as recorded on the source material. The elevation of a feature shall be within 0.1 meters of the corresponding value in the source material from which it is derived.

4.2.1.7.1.1.3.5 Verification of Planimetry Simulation-significant Fixtures. This requirement shall be verified by inspection, analysis and test. Analysis of the planimetric database shall show that the feature density requirements are met. Inspection of the data used in the simulator shall verify the precision of feature elevation and location. A computer program shall test tenability. A computer program shall randomly select 100 points on features or feature boundaries in the planimetric simulation-significant fixtures. The program shall then verify location of each point is within 1 meter of the corresponding point in the source data. A computer program to test vertical tenability shall randomly select 100 points within features in the planimetric simulation-significant fixtures and compare the elevation of these points with the corresponding points in the source data. The program shall then verify that the elevations of the points agree within 0.1 meters. In addition locations of the ends of each runway shall be measured manually by moving the aircraft to the end of the runway and measuring position on the aircraft's inertial navigation system. The requirement to land the aircraft at each airfield shall be verified by demonstration.

3.7.1.1.4 Texture. Texture shall be superimposed on terrain and planimetry as specified in the following subparagraphs. Texture imagery shall be maintained stable, and texture-map continuity shall be maintained across surface boundaries. Texture shall be of one of the following types: (1)

a. Algorithmically generated texture shall superimpose patterns typical of the real-world terrain and features on the simulated surfaces. These patterns shall be generated using an algorithm that considers the type of surface simulated.

b. Geotypical texture shall superimpose patterns typical of the real-world terrain and features on the simulated surfaces. The patterns shall be based on images of real features and terrain similar to the real-world terrain and features being simulated.

c. Geospecific texture shall superimpose real-world images of the actual terrain and features on the corresponding simulated terrain and features. The imagery shall be properly aligned with the simulated terrain and features such that edges match, altitudes are correct, appearance is correct from all directions, etc.

__2__.

4.2.1.7.1.1.4 Verification of Texture. This requirement shall be verified by inspection (3)and demonstration. Inspection, during the design process, of the geographic data used in the simulator shall ensure topographic configuration meets all requirements. (3)A demonstration shall verify each of the heterogeneous configurations affects simulator systems in accordance with this specification.

RATIONALE

This paragraph establishes requirements for texture information that is to be used as photographic texture over an underlying terrain model or feature model. Texture adds realism to sensor and visual presentations. This section describes how the total texture data set is required to vary in terms of heterogeneity; i.e., it defines how subsections of the overall area of geographic coverage are to be organized such that areas of higher data content correspond to areas of greatest training interest. It is here that specific texture requirements for "Fixtures" -- airfields, corridors, waypoints, etc. -- are initially

identified. The requirements associated with each of these fixtures are then specified in the following paragraphs.

Requirements Guidance:

1. Delete any definitions that are not required.

If only uniform texture coverage is required, only one of the three definitions should be retained. In this case, delete the phrase "Texture shall be one of the following types:" that precedes (1).

2. In blank (2), describe the imagery data organization.

If only uniform texture coverage is required insert, "The texture background area shall consist of the entire area of geographic coverage." In this case paragraphs 3.7.1.1.4.2 to 3.7.1.1.4.5 should be deleted.

Verification Guidance:

3. Delete "and demonstration" and the last sentence if the area of geographic coverage is homogeneous.

EXAMPLES
Example 1. A complex Weapon System Trainer PIDS.

3.7.1.1.4 Texture. Texture shall be superimposed on terrain and planimetry as specified in the following subparagraphs. Texture imagery shall be maintained stable, and texture-map continuity shall be maintained across surface boundaries. Texture shall be of one of the following types:

a. Algorithmically generated texture shall superimpose patterns typical of the real-world terrain and features on the simulated surfaces. These patterns shall be generated using an algorithm that considers the type of surface simulated.

b. Geotypical texture shall superimpose patterns typical of the real-world terrain and features on the simulated surfaces. The patterns shall be based on images of real features and terrain similar to the real-world terrain and features being simulated.

c. Geospecific texture shall superimpose real-world images of the actual terrain and features on the corresponding simulated terrain and features. The imagery shall be properly aligned with the simulated terrain and features such that edges match, altitudes are correct, appearance is correct from all directions, etc.

The texture configuration shall be as follows:

a. Texture proximity-significant fixtures shall include two 100 nautical mile wide corridors. The first shall be centered on, and run the entire north-south length of, the Gaming Area. The second shall be centered on a diagonal line running from 27°00'00"N 84°00'00"W to 35°00'00"N 102°00'00"W.

b. Texture navigation-significant fixtures consist of two nautical mile radius circles about each of the following points: 28°15'15"N 85°50'05"W; 29°00'00"N 86°14'30"W, 30°12'45"N 86°12'25"W, 36°12'24"N 88°24'35"W, 39°00'00"N 100°05'15"W, 32°23'45"N 92°00'00"W, 33°13'35"N 98°21'32"W, and 34°14' 57"N 101°34'45"W.

c. A single texture mission-significant fixture shall consist of a ten nautical mile radius circle centered at 33°37'45"N 101°15'35"W.

d. Texture simulation-significant fixtures shall consist of the airfields and immediate surrounding areas at Podunk AL, Peanuts GA, World's End TN, and Big Rock Ark.

e. The texture background area shall consist of all the remaining area of geographic coverage.

Example 2. A system specification where areas of texture heterogeneity match those of terrain and planimetry heterogeneity.

3.7.1.1.4 Texture. Texture shall be superimposed on terrain and planimetry as specified in the following subparagraphs. Texture imagery shall be maintained stable, and texture-map continuity shall be maintained across surface boundaries. Texture shall be of one of the following types:

a. Algorithmically generated texture shall superimpose patterns typical of the real-world terrain and features on the simulated surfaces. These patterns shall be generated using an algorithm that considers the type of surface simulated.

b. Geotypical texture shall superimpose patterns typical of the real-world terrain and features on the simulated surfaces. The patterns shall be based on images of real features and terrain similar to the real-world terrain and features being simulated.

c. Geospecific texture shall superimpose real-world images of the actual terrain and features on the corresponding simulated terrain and features. The imagery shall be properly aligned with the simulated terrain and features such that edges match, altitudes are correct, appearance is correct from all directions, etc.

The texture configuration shall be as follows:

a. Texture proximity-significant fixtures shall include the same area as terrain proximity-significant fixtures.

b. Texture navigation-significant fixtures shall consist of the identical areas as terrain navigation-significant fixtures .

c. The texture mission-significant fixture shall be identical to the terrain mission-significant fixture.

d. Texture simulation-significant fixtures shall consist of identical areas to the terrain simulation-significant fixtures.

e. The texture background area shall consist of all the remaining area of geographic coverage.

Example 3. Only uniform coverage is required. Only one type of texture is required. Note that in this case paragraphs 3.7.1.1.4.2 to 3.7.1.1.4.5 and should be deleted.

3.7.1.1.4 Texture. Texture shall be superimposed on terrain and planimetry as specified in the following subparagraphs. Texture imagery shall be maintained stable, and texture-map continuity shall be maintained across surface boundaries. Geotypical texture shall superimpose patterns typical of the real-world terrain and features on the simulated surfaces. The patterns shall be based on images of real features and terrain similar to the real-world terrain and features being simulated. The texture background area shall consist of the entire area of geographic coverage.

3.7.1.1.4.1 Texture Background Area. __1__ shall be superimposed on all terrain and features in the texture background area. The texture resolution shall be __2__.

4.2.1.7.1.1.4.1 Verification of Texture Background Area. This requirement shall be verified by inspection and analysis. Texture shall be observed on __3__. Resolution shall be analyzed during the design review process.

RATIONALE
This is a paragraph of a section that defines the minimum requirements for texture across the entire area for which geographic information is defined. Specification paragraphs that follow will put more stringent requirements on subsets of the overall area, but in no case will they be less stringent than the background requirements. If the texture requirements are homogeneous, paragraphs' 3.7.1.4.3 to 3.7.1.4.6 and their subparagraphs should be deleted.

Requirements Guidance:

1. *Specify algorithmically generated texture, geotypical texture, or geospecific texture.*

2. *Specify the resolution of the texture pattern.*

Verification Guidance:

3. *Specify where texture should be observed.*

EXAMPLES
3.7.1.1.4.1 Texture Background Area. Algorithmically generated texture shall be superimposed on all terrain and features in the texture background area. The texture resolution shall be 300 feet.

4.2.1.7.1.1.4.1 Verification of Texture Background Area. This requirement shall be verified by inspection and analysis. Texture shall be observed on the visual display. Resolution shall be analyzed during the design review process.

3.7.1.1.4.2 Texture Proximity-significant Fixtures. __1__ shall be superimposed on all terrain and features in (each/the) texture proximity-significant fixture. The texture resolution shall be __2__.

4.2.1.7.1.1.4.2 Verification of Texture Proximity-significant Fixtures. This requirement shall be verified by inspection and analysis. Texture shall be observed on __3__. Resolution shall be analyzed during the design review process.

RATIONALE
This paragraph defines the requirements for those fixtures within the overall environment for which special requirements exist in proximity to nominal aircraft flight paths; for example, corridors might be proximity-significant fixtures.

Requirements Guidance:

1. *Specify algorithmically generated texture, geotypical texture, or geospecific texture.*

2. *Specify the resolution of the texture pattern.*

Verification Guidance:

3. *Specify where texture should be observed.*

EXAMPLES
3.7.1.1.4.2 Texture Proximity-significant Fixtures. Geotypical texture shall be superimposed on all terrain and features in each texture proximity-significant fixture. The texture resolution shall be 48 feet.

4.2.1.7.1.1.4.2 Verification of Texture Proximity-significant Fixtures This requirement shall be verified by inspection and analysis. Texture shall be observed on the visual display. Resolution shall be analyzed during the design review process.

3.7.1.1.4.3 Texture Navigation-significant Fixtures. __1__ shall be superimposed on all terrain and features in (each/the) texture significant fixture. The texture resolution shall be __2__.

4.2.1.7.1.1.4.3 Verification of Texture Navigation-significant Fixtures. This requirement shall be verified by inspection and analysis. Texture shall be observed on __3__. Resolution shall be analyzed during the design review process.

RATIONALE
This paragraph defines those fixtures for which special requirements exist due to the particularly stringent metrics associated with navigation, but not necessarily in proximity to nominal aircraft flight paths. Radar offset aimpoints are typical of this class; while distant, they require special treatment in the environment definition.

Requirements Guidance:

1. *Specify algorithmically generated texture, geotypical texture, or geospecific texture.*

2. *Specify the resolution of the texture pattern.*

Verification Guidance:

3. *Specify where texture should be observed.*

EXAMPLES
3.7.1.1.4.3 Texture Navigation-significant Fixtures. Geospecific texture shall be superimposed on all terrain and features in the texture significant fixture. The texture resolution shall be 10 meters.

4.2.1.7.1.1.4.3 Verification of Texture Navigation-significant Fixtures. This requirement shall be verified by inspection and analysis. Texture shall be observed on the FLIR display. Resolution shall be analyzed during the design review process.

3.7.1.1.4.4 Texture Mission-significant Fixtures. __1__ shall be superimposed on all terrain and features in (each/the) texture mission-significant fixture. The texture resolution shall be __2__.

4.2.1.7.1.1.4.4 Verification of Texture Mission-significant Fixtures. This requirement shall be verified by inspection and analysis. Texture shall be observed on __3__. Resolution shall be analyzed during the design review process.

RATIONALE
This paragraph defines those fixtures for which special requirements exist as a result of their being targets or other high-interest, mission-specific locations. This class of fixtures has been defined in the event that the normal "proximity-significant" class is inadequate for certain situations; otherwise, this class may be unnecessary.

Requirements Guidance:

1. *Specify algorithmically generated texture, geotypical texture, or geospecific texture.*

2. *Specify the resolution of the texture pattern.*

Verification Guidance:

3. *Specify where texture should be observed.*

EXAMPLES
3.7.1.1.4.4 Texture Mission-significant Fixtures. Geospecific texture shall be superimposed on all terrain and features in each texture mission-significant fixture. The texture resolution shall be 10 feet.

3.7.1.1.4.4 Verification of Texture Mission-significant Fixtures. This requirement shall be verified by inspection and analysis. Texture shall be observed on the visual display. Resolution shall be analyzed during the design review process.

3.7.1.1.4.5 Texture Simulation-significant Fixtures. __1__. __2__ shall be superimposed on all terrain and features in (each/the) texture simulation-significant fixture. The texture resolution shall be __3__.

4.2.1.7.1.1.4.5 Verification of Texture Simulation-significant Fixtures. This requirement shall be verified by inspection, analysis, and demonstration. Texture shall be observed on __4__. Resolution shall be analyzed during the design review process. __5__.

RATIONALE
This paragraph describes fixtures for which special requirements exist as a result of the nature of the simulation itself. For example, "landable" airfields will be identified here since -- unlike other terrain features -- contact with them by the simulated aircraft will not generate a crash condition.

Requirements Guidance:

1. *Describe the unique properties of simulation-significant features, e.g., landable airfields.*

2. *Specify algorithmically generated texture, geotypical texture, or geospecific texture.*

3. *Specify the resolution of the texture pattern.*

Verification Guidance:

4. *Specify where texture should be observed.*

5. *Describe how the demonstration should be conducted.*

EXAMPLES
3.7.1.1.4.5 Texture Simulation-significant Fixtures. Texture simulation-significant fixtures are identical to topographic simulation-significant fixtures. Geotypical texture shall be superimposed on all terrain and features in each texture simulation-significant fixture. The texture resolution shall be 1 foot.

4.2.1.7.1.1.4.5 Verification of Texture Simulation-significant Fixtures. This requirement shall be verified by inspection and analysis. Texture shall be observed on the visual display. Resolution shall be analyzed during the design review process.

3.7.1.1.5 Cartographic. __1__.

4.2.1.7.1.1.5 Verification of Cartographic. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by inspection of charts and data used in the simulator.

RATIONALE
The section establishes requirements for cartographic information to be included within the overall environment description. In certain simulators the geographic environment is not a real-world representation, but is a typical scene or a composite of areas. In this case -- where the aircraft has a map display, etc., or charts are needed -- this paragraph should be filled in to describe the requirement. If the real world is represented, this paragraph will be unnecessary.

Requirements Guidance:

1. Describe the requirement for cartographic information.

EXAMPLES
3.7.1.1.5 Cartographic. The simulator shall include continuous data for the Digital Map System across the entire area of geographic coverage in Defense Mapping Agency Vector Product Format. It shall also include charts for the area of geographic coverage in Operational Navigation Chart (ONC) format.

3.7.1.1.6 Geographic Information Sources. Geographic information shall be based on __1__.

4.2.1.7.1.1.6 Verification of Geographic Information Sources. This requirement shall be verified by inspection of the data sources.

RATIONALE
In order to maximize contractor responsibility for design, it is recommended that the contractor be responsible for obtaining his own data. However, this is often not possible or desirable (e.g., when the government has good databases covering the area, or when interoperability with other simulators is required).

There are several possible data sources:

a. The Simulator Data Base Facility (SDBF) was established as a repository of simulator databases at Kirtland Air Force Base at the completion of Project 2851. Data are available in two formats: (1) Standard Simulator Data Base (SSDB) Interchange Format (SIF) Design Standard per MIL-STD-1821, and (2) Generic Transformed Data Base Design Standard per MIL-STD-1820. Data deliveries from the SDBF are made both from the active (edited, processed, and merged with existing data) and passive (not processed or changed by the facility) databases. Data deliveries are subject to the release restrictions of the sources used to create the database.

The SDBF supports visual, radar, infrared and night-vision goggle database applications. The Standard Interchange Format can provide a high level of detail, but it is not available for all areas and high detail records are often not populated. The data that reside in the SSDB contain only what has been received. Not every data product in the SDBF will contain all the information to support every sensor system.

The SDBF product catalog will be updated monthly, and is available on the World Wide Web (WWW) at http://sdbf.irk.aetc.af.mil/users/html/sdbf.html and on the internet via anonymous ftp at sdbf.irk.aetc.af.mil. Requests for a product from the SDBF require the purchasing organization to have a government contract, and the SDBF product must be used on that contract.

For information, contact the SDBF from 0800 - 1700 Monday through Friday Mountain Standard Time.

Simulator Data Base Facility
P.O. Box 9560
Albuquerque NM 87119
Phone: (505) 262-9340
Fax: (505) 262-9331
E-Mail: sdbf@sdbf.irk.aetc.af.mil

b. Defense Mapping Agency (DMA) products are typically Digital Terrain Data and Digital Feature Analysis Data. These data are available from DMA, but highly detailed data on particular areas of interest may not be available. These data require both enhancement and processing for simulator use.

Requisitions for catalog volumes and digital data products should be forwarded to:
DMA Combat Support Center
ATTN: CCOR, Stop D-17
6001 MacArthur Blvd.
Bethesda MD 20816-5001
Phone: (301) 227-2495 or (800) 826-0342
Fax: (301) 227-2498

c. Satellite photography is available from DMA and other government and commercial sources. In many cases these data may be highly classified.

Requirements Guidance:

1. If no specific source(s) are to be specified, delete the paragraph. Otherwise, identify any required data sources and identify enhancements necessary in blank (1).

Process Guidance:

The Statement of Work should:
-- Require government review or approval of data sources if none are specified here.
-- Identify data sources the government will make available, but not require.
-- Require "error correction", i.e., removal of unnatural anomalies when DMA information is required or made available.

EXAMPLES
3.7.1.1.6 Geographic Information Sources. Geographic information shall be based on MIL-STD-1821 Standard Interchange Format where such data are available.

3.7.1.2 Geodetic. (1)Magnetic and gravimetric variation shall be simulated in accordance with the following subparagraphs.

4.2.1.7.1.2 Verification of Geodetic. Verification of this requirement is not applicable.

RATIONALE
Requirements Guidance:

1. Tailor the sentence following (1) to be consistent with the requirement. If there is no requirement for simulation of magnetic or gravimetric variation, change the requirement to read "Not applicable".

Verification Guidance:

"Not applicable" since this is a lead in paragraph only.

3.7.1.2.1 Magnetic Variation. Magnetic variation shall match the source data to within __1__ degree(s) throughout the gaming area __2__. __3__.

4.2.1.7.1.2.1 Verification of Magnetic Variation. This requirement shall be verified by test. The simulated aircraft shall be placed at __4__ randomly selected locations in the gaming area and its true and magnetic headings compared to ensure their difference is equal to the required magnetic variation within the specified tolerance.

RATIONALE

This section identifies magnetic variation data to be included within the environment. This information is used to drive a magnetic compass in a manner consistent with the navigation charts used in the trainer. If simulation of a magnetic compass is not required, delete this paragraph.

Requirements Guidance:

1. Enter the required accuracy; +/- 1 degree is a typical value that has been used. This should be applied only within given gaming or operating areas (as stated in the recommended requirement text) since individual magnetic variation models cover various segments of the world; a more global requirement (e.g., if the accuracy were not constrained to apply within gaming areas only) would imply the implementation of more models than are actually needed for the application.

2. State any exceptions; these would typically include areas close to the earth's magnetic poles since significantly more data are needed to accurately model magnetic variation in these areas.

3. State whether or not local disturbances should be included. If they are, these areas should also meet the accuracy requirement; otherwise they are exceptions to the requirement and the required accuracy must be separately specified.

Verification Guidance:

4. Enter the number of points at which the test will be performed. Twenty should be adequate for small gaming areas and 100 for large gaming areas.

EXAMPLES

3.7.1.2.1 Magnetic Variation. Magnetic variation data shall match the source data to within +/- 1 degree throughout the gaming area except for areas within 1500 km of the earth's magnetic poles. Local magnetic disturbances shall be simulated.

4.2.1.7.1.2.1 Verification of Magnetic Variation. This requirement shall be verified by test. The simulated aircraft shall be placed at 100 randomly selected locations in the gaming area and its true and magnetic headings compared to ensure their difference is equal to the required magnetic variation within the specified tolerance.

3.7.1.2.2 Gravimetric. Gravimetric variation data shall match the source data to within __1__ degree(s) throughout the gaming area __2__. __3__.

4.2.1.7.1.2.2 Verification of Gravimetric. This requirement shall be verified by test. __4__

RATIONALE
This section establishes requirements for gravity anomaly data to be included in the environment. This is needed only when a very accurate inertial navigation system simulation is included; if there is no such requirement , delete this paragraph. No current simulators model the earth's gravitational field, so there is no experiential basis on which to provide guidance.

Requirements Guidance:

1. *Enter the required accuracy*

2. *State any exceptions.*

3. *State whether or not local disturbances should be included.*

Verification Guidance:

4. *Fill in test details.*

3.7.1.3 Atmospheric. The atmospheric simulation shall: __1__

4.2.1.7.1.3 Verification of Atmospheric. This requirement shall be verified by test. The test shall vary atmospheric parameters to the extent required herein and illustrate the required effects.

RATIONALE
Atmospheric simulation has varied widely in both fidelity and extent on past simulators. Almost all approaches have provided for instructor control of atmospheric parameters. Pressure pattern navigation and limited visibility have been provided (e.g., B-52 WST). Visibility on visual systems has been simulated (in clouds/not in clouds) but sophisticated cloud effects have not been simulated. Infrared simulations have typically been limited to one time of day and one season of the year. Only the SOF ATS has used dynamic weather.

Requirements Guidance:

1. *Select as many of the following as applicable:*

    a. *Affect the aerodynamic performance of the simulated air vehicle in accordance with physical laws.*

    b. *Affect the air data system of the simulated air vehicle in accordance with physical laws.*

    c. *Affect the instruments of the simulated air vehicle in accordance with physical laws.*

    d. *Provide simulated pressure pattern navigation.*

    e. *Affect visibility in the simulated visual scene.*

    f. *Affect the appearance of the environment in the visual scene.*

    g. *Affect the appearance of the environment on simulated air vehicle sensors.*

h. Affect propagation of simulated non-visible electromagnetic energy received by the simulated air vehicle and entities.

i. Affect the simulated aerodynamic performance of entities.

j. Affect runway conditions.

EXAMPLES
Example 1. A primary training aircraft simulator.

3.7.1.3 Atmospheric. The atmospheric simulation shall:

a. Affect the aerodynamic performance of the simulated air vehicle in accordance with physical laws.

b. Affect the air data system of the simulated air vehicle in accordance with physical laws.

c. Affect the instruments of the simulated air vehicle in accordance with physical laws.

d. Affect visibility in the simulated visual scene.

e. Affect runway conditions.

Example 2. A sophisticated Special Operations Forces Mission Rehearsal Device.

3.7.1.3 Atmospheric. The atmospheric simulation shall:

a. Affect the aerodynamic performance of the simulated air vehicle in accordance with physical laws.

b. Affect the air data system of the simulated air vehicle in accordance with physical laws.

c. Affect the instruments of the simulated air vehicle in accordance with physical laws.

d. Affect visibility in the simulated visual scene.

e. Affect the appearance of the environment in the visual scene.

f. Affect the appearance of the environment on simulated air vehicle sensors.

g. Affect propagation of simulated non-visible electromagnetic energy received by the simulated air vehicle and entities.

3.7.1.3.1 Atmospheric Representation. Except as required by paragraphs 3.7.1.3.1.1 and 3.7.1.3.1.2, the atmospheric simulation shall be horizontally __1__, vertically __2__, and __3__. (4) Atmospheric parameters shall vary upon command. __5__. (6) Atmospheric parameters shall be commanded at __7__ __8__ latitude/longitude points in the gaming area (9) and at __10__ different altitudes __11__. Values of atmospheric parameters shall be interpolated between points or extrapolated as necessary to meet the requirements of this specification. (12) Atmospheric parameters shall automatically vary with time. __13__.

4.2.1.7.1.3.1 Verification of Atmospheric Representation. This requirement shall be verified by test. The test shall verify that:

a. The atmospheric representation is horizontally __1__, vertically __2__, and __3__.

(14) b. The required parameters can be commanded at each required point.

(14) c. That atmospheric parameters are interpolated or extrapolated as required.

(14) d. That atmospheric parameters vary with time as required.

(14) e. That sets of atmospheric parameters are consistent with each other in terms of real-world atmospheric conditions.

RATIONALE

NOTE REGARDING ATMOSPHERIC SIMULATION CLASSIFICATION:

Atmospheric simulation is classified as follows:

a. Horizontally uniform (i.e., there is no variation of any atmospheric parameter at any latitude or longitude) in the gaming area OR horizontally non-uniform (i.e., atmospheric parameters vary with latitude and longitude).

b. Vertically uniform (i.e., there is no variation in any atmospheric parameter with altitude) OR vertically standard (i.e., pressure and temperature vary with altitude in accordance with a standard atmospheric model, such as specified in MIL-STD 210 "Climatic Information to Determine Design and Test Requirements for Military Systems and Equipment") OR vertically non-uniform (i.e., atmospheric parameters vary with altitude).

c. Static (i.e., atmospheric parameters do not vary automatically with time) OR dynamic (i.e., atmospheric parameters vary automatically with time).

d. Commanded -- in addition to other requirements, the atmospheric parameters vary by command. While adequate for many applications, this does not ensure consistency (e.g., snow could occur at a temperature of 100 degrees F).

NOTES REGARDING RUNWAY VISIBILITY RANGE (RVR) & RUNWAY CONDITION READING (RCR):

RVR is a direct indicator of visibility at the runway, which -- in the real world -- can be a function of a number of weather-related factors (see AFM 51-37 "Flying Training -- Instrument Flying", chapter 14).

RCR is a direct indicator of runway slickness, which -- in the real world -- is similarly a function of a number of weather-related factors (reference T.O. 33-1-23 "Procedures for Use of Decelerometer to Measure Runway Slickness"). RCR is reported as a two digit number between 01 and 26 (the low end of the scale corresponds to ice, while the high end corresponds to dry concrete).

In the simulator, RVR and RCR provide the instructor or operator a calibrated metric for establishing visibility and stopping distance (without the need for defining a combination of parameters to achieve the desired result). In image generators, RVR is typically controlled independently of other atmospheric parameters as a subjectively calibrated "haze" (if RVR is inactive, runway visibility resulting from the combination of other atmospheric parameters will simply be whatever it is, and not have a calibration reference). Similarly, RCR provides a quantitative metric for the simulation to determine how the simulated aircraft should react with the runway. If these parameters are active, they should override the combined effects of other atmospheric parameters at the runway. Further, since RVR and RCR are independent of other parameters, they should normally change only upon command.

Requirements Guidance:

1. Choose "uniform" or "non-uniform".

2. Choose "uniform", "standard" or "non-uniform".

3. Choose "static" or "dynamic".

4. Delete this sentence if commanded atmospheric parameters are not required.

5. This blank should address the requirement for consistency across the entire set of atmospheric parameters. Some possible requirements are:

a. Leave blank -- no consistency is required. It is the responsibility of the person setting up automatic or manual commands to achieve any required consistency.

b. "The simulation shall automatically ensure that atmospheric parameters are consistent with each other and physical laws."

c. "The simulation shall automatically ensure that atmospheric parameters, other than runway visual range (RVR) and runway condition reading (RCR), are consistent with each other and physical laws. When active, RVR and RCR shall override the effects of other atmospheric parameters in determining runway visibility and conditions."

d. "The simulation shall automatically ensure that atmospheric parameters, other than runway condition reading (RCR), are consistent with each other and physical laws; when runway visual range (RVR) is active, other atmospheric parameters shall be automatically adjusted to ensure this consistency. When active, RCR shall override the effects of other atmospheric parameters in determining runway conditions."

6. Delete the next two sentences if the atmospheric simulation is horizontally uniform and vertically uniform or standard.

7. Specify the number of points where atmospheric parameters may be commanded. Delete all text through blank (10) if the atmospheric simulation is horizontally uniform and vertically non-uniform.

8. Specify how the points will be arranged.

9. Delete the remainder of the sentence if the atmospheric simulation is vertically uniform or standard.

10. Specify the number of different altitudes at which the atmospheric parameters may be commanded.

11. Relate the altitudes to the latitude/longitude points (e.g., "for each latitude/longitude point"). Delete if the atmospheric simulation is horizontally uniform.

12. Delete if the atmospheric simulation is static. This does not preclude commanding new conditions during an exercise.

13. Specify how the atmospheric simulation varies with time.

Verification Guidance:

14. Select from items b through e to be consistent with the tailored requirement.

Process Guidance: *If runway visibility range (RVR) or runway condition reading (RCR) is a stated requirement in paragraph 3.7.1.3.1.1, the consistency between RVR, RCR, and other atmospheric parameters must be specified in this paragraph. One approach for handling RVR is to adjust other atmospheric parameters to force consistency with the commanded RVR value -- but this can affect visibility other than at the runway, and may not be acceptable to the user. If the desired implementation is not well defined at RFP preparation, a process should be established to define and document the required implementation in this specification after contract award.*

EXAMPLES
Example 1. A primary training aircraft simulator. This is a continuation of the example from paragraph 3.7.1.3.

3.7.1.3.1 Atmospheric Representation. Except as required by paragraphs 3.7.1.3.1.1 and 3.7.1.3.1.2, the atmospheric simulation shall be horizontally uniform, vertically standard, and static. Atmospheric parameters shall vary upon command. The simulation shall automatically ensure that atmospheric parameters, other than runway condition reading (RCR), are consistent with each other and physical laws; when runway visual range (RVR) is active, other atmospheric parameters shall be automatically adjusted to ensure this consistency. When active, RCR shall override the effects of other atmospheric parameters in determining runway conditions.

4.2.1.7.1.3.1 Verification of Atmospheric Representation. This requirement shall be verified by test. The test shall verify that:

a. The atmospheric representation is horizontally uniform, vertically standard, and static.

b. The required parameters can be commanded at each required point.

c. That sets of atmospheric parameters are consistent with each other in terms of real-world atmospheric conditions.

Example 2. A sophisticated Special Operations Forces Mission Rehearsal Device. This is a continuation of the example from paragraph 3.7.1.3.1. The complex simulation required by this paragraph would require a computer support program to convert real weather data into a simulator mission script to initialize the simulation.

3.7.1.3.1 Atmospheric Representation. Except as required by paragraphs 3.7.1.3.1.1 and 3.7.1.3.1.2, the atmospheric simulation shall be horizontally non-uniform, vertically non-uniform, and dynamic. Atmospheric parameters shall vary upon command. Commands shall be limited such that atmospheric parameters remain consistent with each other and real-world atmospheric conditions. Atmospheric parameters shall be commanded at 1000 evenly spaced latitude/longitude points in the gaming area and at three different altitudes for each latitude/longitude point. Values of atmospheric parameters shall be interpolated between points or extrapolated as necessary to meet the requirements of this specification. Atmospheric parameters shall automatically vary with time. The time variation shall be based on rates of change commanded for each parameter at each point specified above.

4.2.1.7.1.3.1 Verification of Atmospheric Representation. This requirement shall be verified by test. The test shall verify that:

a. The atmospheric representation is horizontally uniform, vertically standard, and static.

b. The required parameters can be commanded at each required point.

c. That atmospheric parameters are interpolated or extrapolated as required.

d. That atmospheric parameters vary with time as required.

e. That sets of atmospheric parameters are consistent with each other in terms of real-world atmospheric conditions.

3.7.1.3.1.1 Atmospheric Parameters. The following atmospheric parameters shall be represented: (1)

a. Temperatures from __2__ to __3__. __4__.

b. Wind from __2__ to __3__ in any direction. Gusts from __2__ to __3__ in any direction. __4__.

c. Turbulence from __2__ to __3__. __4__.

d. Barometric pressure from __2__ to __3__. __4__.

e. Humidity from __2__ to __3__. __4__.

f. Precipitation intensity from __2__ to __3__. Precipitation types shall include rain, snow, fog, and haze. __4__.

g. Thunderstorm conditions from __2__ to __3__. __4__.

h. Lightning (bolts and random light flashes) from __2__ to __3__. __4__.

i. Clouds (% sky cover) from __2__ to __3__. Cloud base (ceiling) from __2__ to __3__. Cloud thickness from __2__ to __3__. Scud (randomly varying cloud density) shall be commanded off or on. __4__.

j. Ground Fog from __2__ to __3__, with the fog top from __2__ to __3__. Patchy fog (randomly varying fog density) shall be commanded off or on. __4__.

k. Visibility from __2__ to __3__. __4__.

l. Ground cover from __2__ to __3__. __4__.

m. Rates of change of the above parameters.

n. Blowing snow and blowing dust shall be simulated. __4__.

o. Runway visibility range (RVR) from __2__ to __3__. This parameter shall be commanded active or inactive, and shall be static.

p. Runway condition reading (RCR) from __2__ to __3__. This parameter shall be commanded active or inactive, and shall be static.

4.2.1.7.1.3.1.1 Verification of Atmospheric Parameters. This requirement shall be verified by demonstration. The demonstration shall verify that each required parameter can be commanded through its entire range.

(5) Demonstration shall verify that blowing snow and blowing dust are simulated in accordance with the requirements of this specification.

(6) The procedures of the "Airplane Flight Simulator Evaluation Handbook" shall be used to verify the visual appearance of the following atmospheric parameters. (7) Visual observation shall verify that the weather radar display is correlated with the out-the-window display.

(8) a. Runway visual range shall be verified in accordance with Section 4c "Visual System RVR Calibration".

(8) b. Thunderstorm conditions shall be verified in accordance with Section 4f "Weather Effects".

(8) c. Ground cover appearance shall be verified in accordance with Section 4f "Weather Effects".

(8) d. Cloud appearance shall be verified in accordance with Section 4f "Weather Effects".

(8) e. Ground fog appearance shall be verified in accordance with Section 4f "Weather Effects".

RATIONALE

NOTES REGARDING CLOUDS AND SCUD:

Although cloud covers of less than 100% (along with shading effects of broken clouds on the terrain) can be displayed, it should be recognized that -- in general -- only generic terrain or sky will be seen through holes in the clouds. If it is a requirement that entities or terrain in the scene actually be viewed through holes in the clouds, this should be stated explicitly in the image generator section (paragraph 3.7.2.2). Such a requirement could be a resource driver since either the clouds would have to be modeled as individual entities, or the texture pattern used to produce the image of a partially cloudy sky would have to be tested for hole locations (which could substantially drive the required image generator capability).

Scud is typically displayed in transition zones above the cloud tops and below the cloud base as a randomly varying cloud density. Normally it is adequate to be able to command scud on or off; if other variations of scud simulation are required (e.g., uniform to patchy), the required effect must be clearly stated.

NOTE REGARDING VISIBILITY: The maximum required value for visibility should correspond to the maximum computed range of the image generator. This is the distance at which the lowest level of detail transitions into the scene. This value should be chosen with care. As this value increases, the image generator needs to accommodate a larger active data base and process a larger load (which increases cost or reduces overall database density). Typical values are 15 to 25 nautical miles.

Requirements Guidance:

1. Delete from list if not required.

2. Specify minimum required value.

3. Specify maximum required value.

4. State any differences from the overall requirement using horizontally uniform, horizontally non-uniform, vertically uniform, vertically non-uniform, static and dynamic.

Verification Guidance:

5. Delete all text following (5) if there is no requirement for out-the-window visual simulation. Delete the sentence following (5) if there is no requirement for blowing snow or dust in the tailored requirement.

6. Using the "Airplane Flight Simulator Evaluation Handbook" test procedures to run the subjective appearance evaluations will provide consistency with commercial practice. If commercial practices are inappropriate for these evaluations (e.g., if all the atmospheric parameters required to conduct the test

are not included in the tailored requirement), specify modifications to the commercial test or substitute the details of the appropriate procedures.

7. Delete the sentence following (7) if there is no weather radar simulation.

NOTES REGARDING THE COMMERCIAL TEST PROCEDURES: Section 4c specifies a 20% tolerance for the visual ground segment (VGS). Section 4f verifies the appearance of light, medium, and heavy precipitation by flying near a thunderstorm under the appropriate conditions; the appearance of a wet and snow-covered runway is verified; an approach profile is used to verify the appearance of variable cloud density, scattered to broken cloud deck, gradual break out, patchy fog, and the effect of fog on airport lighting.

8. Select from items a through e to be consistent with the tailored requirement.

Process Guidance:

It may be necessary or desirable to let the contractor fill in these blanks as part of a source selection, or in accordance with a Statement of Work task with appropriate requirements for update at PDR and CDR.

EXAMPLES

Example 1. A primary training aircraft simulator. This is a continuation of the example from paragraph 3.7.1.3.1. Note that in this case, there is no mechanism to prevent command of inconsistent atmospheric conditions.

3.7.1.3.1.1 Atmospheric Parameters The following atmospheric parameters shall be represented:

a. Temperatures from -40 to 70 degrees C. Temperature shall be commanded at the surface.

b. Wind from 0 to 150 knots in any direction. Gusts from 0 to 50 knots in any direction. Wind shall be commanded at the surface and at altitudes of 5000 and 15000 feet MSL.

c. Turbulence from none to severe.

d. Barometric pressure from 29 to 31 inches Hg.

e. Clouds (% sky cover) from 0 to 100%. Cloud base (ceiling) from 0 feet to aircraft service ceiling. Cloud thickness from 0 to 15000 feet. Scud (randomly varying cloud density) shall be commanded off or on.

f. Visibility from 0 to 15 nautical miles.

g. Runway visibility range (RVR) from 0 to 12000 feet. This parameter shall be commanded active or inactive, and shall be static.

h. Runway condition reading (RCR) from 06 to 24. This parameter shall be commanded active or inactive, and shall be static.

Example 2. A sophisticated Special Operations Forces Mission Rehearsal Device. This is a continuation of the example from paragraph 3.7.1.3.1.

3.7.1.3.1.1 Atmospheric Parameters. The following atmospheric parameters shall be represented:

a. Temperatures from -80 to 60 degrees C along the ownship's flight path and altitude.

b. Wind from 0 to 200 knots in any direction. Gusts from 0 to 60 knots in any direction. Wind shall be commanded at the surface and at altitudes of 5000 and 15000 feet MSL.

c. Turbulence from none to severe.

d. Barometric pressure from 29 to 31 inches Hg.

e. Humidity from 0 to 100% relative.

f. Precipitation intensity from none to heavy. Precipitation types shall include rain, snow, fog, and haze.

g. Thunderstorm conditions from none to heavy.

h. Lightning (bolts and random light flashes) from none to frequent, varying as a function of thunderstorm intensity.

i. Clouds (% sky cover) from 0 to 100%. Cloud base (ceiling) from 0 feet to aircraft service ceiling. Cloud thickness from 0 to 20000 feet. Scud (randomly varying cloud density) shall be commanded off or on.

j. Ground Fog from none to heavy, with the fog top from 0 to 200 feet. Patchy fog (randomly varying fog density) shall be commanded off or on.

k. Visibility from 0 to 25 nautical miles.

l. Rates of change of the above parameters.

m. Ground cover from 0 to 15 inches of snow. This parameter shall be static.

n. Blowing snow and blowing dust shall be simulated.

o. Runway visibility range (RVR) from 0 to 12000 feet. This parameter shall be commanded active or inactive, and shall be static.

3.7.1.3.1.2 Windshear. __1__ windshear simulation model(s) is(are) required. The windshear model(s) shall conform to __2__. __1__ microburst model(s) is(are) required. The microburst model(s) shall conform to __2__. __3__. The model locations shall be commanded, and shall be __4__. Model states shall be commanded to active or inactive. No more than one model shall be commanded active where the extent of two or more instances of (5) windshear or microburst models overlap.

4.2.1.7.1.3.1.2 Verification of Windshear. This requirement shall be verified by test. The test shall verify that:

a. The model locations can be commanded.

b. Model activity can be commanded on or off, but is mutually exclusive for models with overlapping extents.

c. The atmospheric parameters vary in accordance with the reference model(s).

(6) d. The model parameters can be commanded as required.

(6) e. The model parameters vary with time as required.

(7) f. The procedures of the "Airplane Flight Simulator Evaluation Handbook", Section 2h "Windshear Demonstration", shall be used to verify that the simulation provides adequate recognition cues for the aircrew to execute recovery maneuvers.

RATIONALE

Windshear models have been derived and correlated with actual flight test measurements by several research agencies. Windshear and microburst models should be obtained from recognized sources. The FAA "Windshear Training Aid" is one such source. Any documents referenced in the tailored requirement must also be included under paragraph 2. "Applicable Documents".

The "International Standards for the Qualification of Airplane Flight Simulators" require windshear simulation using models from recognized sources for Level 1 and 2 simulators. Windshear simulation is not required for helicopter simulators (FAA Advisory Circular AC-120-63).

Requirements Guidance:

1. Insert the number of windshear and microburst models to be provided. If no windshear or microburst simulation is required, so state and delete the corresponding sentence containing blank (2).

2. Identify the models to be implemented.

3. If any of the models has variable parameters, indicate the extent of commanded control. If appropriate, also indicate whether these parameters will automatically vary with time.

4. State whether model location shall be static or dynamic.

5. Modify the phrase following (5) to be consistent with the tailored requirement.

Verification Guidance:

6. Select from items d and e to be consistent with the tailored requirement.

7. Using the "Airplane Flight Simulator Evaluation Handbook" test procedures to run the subjective simulation evaluations will provide consistency with commercial practice. If commercial practices are inappropriate for these evaluations (e.g., if the tailored atmospheric simulation requirements are inconsistent with the handbook procedures), specify modifications to the commercial test or substitute the details of the appropriate procedures.

Process Guidance:

It may be necessary or desirable to let the contractor fill in these blanks as part of a source selection, or in accordance with a Statement of Work task with appropriate requirements for update at PDR and CDR.

EXAMPLES

Example 1. A primary training aircraft simulator. This is a continuation of the example from paragraph 3.7.1.3.1.

3.7.1.3.1.2 Windshear. Three windshear simulation models are required. The windshear models shall conform to the FAA Windshear Training Aid Reference Wind Models 1, 2 and 4. No microburst simulation is required. The model locations shall be commanded, and shall be static. Model states shall be commanded to active or inactive. No more than one model shall be commanded active where the extent of two or more instances of windshear models overlaps.

Example 2. A sophisticated Special Operations Forces Mission Rehearsal Device. This is a continuation of the example from paragraph 3.7.1.3.1.

3.7.1.3.1.2 Windshear. Two windshear simulation models are required. The windshear models shall conform to the FAA Windshear Training Aid Reference Wind Models 3 and 4. One microburst model is required. The microburst model shall conform to the UK Royal Aerospace Establishment Microburst Vortex Ring Air Flow Model. The ground footprint diameter of the microburst shall be commanded from 6000 to 10000 feet. The microburst model altitude shall be commanded from 2250 to 4500 feet above the terrain. The model locations shall be commanded, and shall be dynamic. Model states shall be commanded to active or inactive. No more than one model shall be commanded active where the extent of two or more instances of windshear or microburst models overlaps.

3.7.1.3.2 Electromagnetic Signal Attenuation. The atmospheric simulation shall __1__ attenuation of simulated non-visible electromagnetic signals. __2__.

4.2.1.7.1.3.2 Verification of Electromagnetic Signal Attenuation. This requirement shall be verified by test. The test shall verify that each different type of electromagnetic signal required for simulation by this specification is properly attenuated.

RATIONALE

The types of propagation simulation are:

*a. Replicated: S=f(R1,A1)*f(R2,A2)...*f(Rn,An); i.e., the signal strength (S) decreases as range (R) between the emitter and simulated aircraft or simulated aircraft and target increases. A computation is made over each portion of the path where there is a significant change in atmospheric parameters (A).*

b. Partially replicated: S=f(R,Aavg); i.e., the signal strength decreases as range between the emitter and simulated aircraft or simulated aircraft and target increases. The attenuation changes based on composite values (Aavg) of the atmospheric parameters over the each path.

c. Approximated: S= f(R); i.e., the signal strength decreases as range between the emitter and simulated aircraft or simulated aircraft and target increases. Atmospheric effects are constant.

Generally, previous simulations have used approximated or partially replicated simulation.

Requirements Guidance:

1. *Fill in replicate, partially replicate, or approximate.*
2. *Describe the algorithm used.*

Process Guidance:

It is desirable to let the contractor fill in blank (2) as part of a source selection, or in accordance with a Statement of Work task with appropriate requirements for update at PDR and CDR.

EXAMPLES

Example 1. A primary training aircraft simulator. This is a continuation of the example from paragraph 3.7.1.3.1. In this case the paragraph should be deleted.

Example 2. A sophisticated Special Operations Forces Mission Rehearsal Device. This is a continuation of the example from paragraph 3.7.1.3.1.

3.7.1.3.2 Electromagnetic Signal Attenuation. The atmospheric simulation shall replicate the attenuation of simulated non-visible electromagnetic signals. Atmospheric conditions shall be calculated at two mile

intervals along a straight-line path from the aircraft to the emitter or target, and along each radar sweep line. The signal attenuation over that two-mile portion of the path shall be based on the average of the conditions at the beginning and end of the interval.

3.7.1.4 Celestial Objects.

4.2.1.7.1.4 Verification of Celestial Objects. Verification of this requirement is not applicable.

RATIONALE
Requirements Guidance:

This is a title-only, lead-in paragraph.

This section includes requirements for celestial objects (which may include the sun, moon, planets, and stars) to be portrayed in the environment. These may be used for star-tracking navigational systems and sextant simulation, as well as ambient sunlight/moonlight simulation, time-of-day simulation, etc. For night-time mission rehearsal simulation, the moon phase may need to be accurately portrayed.

Delete those subparagraphs corresponding to celestial objects that need not be simulated. If there is no requirement to simulate any of the celestial objects, delete this paragraph and all of its subparagraphs.

3.7.1.4.1 Sun. The sun's appearance and illumination characteristics shall be simulated. __1__. (2)The sun shall (also) assume a stationary position corresponding to a selected time of the day upon command. (3)The appearance of objects in the __3a__ (spectrum/spectra) shall change with the simulated position of the sun in accordance with the requirements of this specification. (4)Sun-cast shadows in the visual scene (shall/may) correspond to the sun's position.

4.2.1.7.1.4.1 Verification of Sun. This requirement shall be verified by demonstration (5)and analysis. The position of the sun shall be verified by demonstration using __6__. (7)The change in the appearance of objects caused by the sun in the __7a__ (spectrum/spectra) shall be verified by demonstration (8)and analysis using __9__. (10)The correct correspondence of cast shadows to sun position shall be demonstrated using __10a__.

RATIONALE
Requirements Guidance:

1. Blank (1) should describe whether the sun's position will be mobile (appear to move across the sky) or whether it will remain in a stationary position throughout a simulated mission. Whether the position of the sun is mobile or stationary depends on whether the primary function of the simulator will be to simulate long (more than 3 hour) or short (less than 3 hour) missions, and the importance of updated sun position to the application. In extended length missions, the position of the sun may be updated on a regular basis. In short missions, it may not be necessary to show the sun moving as the day progresses, but the sun should hold a fixed position representative of the approximate time period and location at which the mission is flown. In a sentence in blank (1), the author must list either each of the time periods for which a static (stationary) sun would have a different position (such as dawn, morning, noon, afternoon, and dusk) or the sentence:
"The position of the sun shall be updated as often as necessary to ensure that the angle between the true line of sight to the sun's position as specified in the approved design criteria and the simulated line of sight to the sun is less than __1a__, and that the sun appears to move smoothly across the visual scene."
where blank (1a) is a tolerance angle with units such as degrees, radians, or arc-seconds.

If a static sun is used, sentences should also be included that list the positions at which the sun will be displayed for each time period. These positions can be described as locations of the sun at a certain time

(e.g., the morning sun is a stationary object displayed where the real-world sun would be at 0900). Multiple static positions may depend on time of year and geographic location as well as time of day (e.g., the morning sun is a stationary object displayed where the real world sun would be at 0900 on the day and place that the exercise is to be simulated). This is important when a pilot needs to know what daytime flying will be like in a possible future mission (e.g., What will the conditions be like when I fly this mission in real life two months from now in Iraq?).

2. Delete the sentence following (2) if commanded sun position is not required. Otherwise tailor the sentence to be consistent with the requirement established in blank (1).

3. If there is no requirement for the appearance of objects to be affected by the position of the sun, delete the sentence following (3). Otherwise retain this sentence, and fill in blank (3a) with the electromagnetic spectrum or spectra to be affected by changes in the sun's position. These could include the visible, infrared or other relevant electromagnetic spectra that are required to reflect effects of the sun's position.

4. If the sentence following (4) is inconsistent with the tailored requirements, delete it (e.g., cases such as Example 2, or in simulators with no requirement for daylight out-the-window visual imagery). Otherwise tailor the sentence following (4) to specify whether sun-cast shadows "shall" or "may" correspond to the simulated sun position. This sentence is intended as a qualification and clarification regarding the illumination characteristics that are to be simulated. A requirement for correlated sun-cast shadow simulation should be avoided unless there is a compelling training or mission rehearsal requirement. Sun-cast shadow simulation can severely impact both offline resources (e.g., shadows appearing on real-world imagery must be removed before its use in geospecific texture maps) and online resources (e.g., simulated shadows must be rendered by the image generator in correspondence to sun position change).

Verification Guidance:

5. If sentence (3) is deleted (i.e., if there is no requirement for the appearance of objects to change as a function of the sun's position) or if changes in the sun's position affect only the visible spectrum, delete the phrase "and analysis" following (5).

6. In blank (6), specify the name of the appropriate visual system(s).

7. If sentence (3) is deleted, delete the sentence following (7). Otherwise retain this sentence and copy the contents of blank (3a) into blank (7a).

8. If change in the sun's position affects only the visible spectrum, delete the phrase "and analysis" following (8).

9. If sentence (3) is deleted or if changes in the sun's position affect only the visible spectrum, blank (9) can simply be filled in with the name of the appropriate visual system(s). If the simulation is to include effects in non-visible spectra as well, an analysis should be performed using a realtime data display linked to the running simulator; the display approach and the data to be analyzed should be specified in blank (9).

10. If the sentence following (4) was deleted or if sun-cast shadows need not (i.e., "may") correspond to the sun's position, delete the sentence following (10). Otherwise specify the name of the appropriate visual system(s) in blank (10a); this would normally be the same as that specified in blank (6).

EXAMPLES

Example 1. For a simulator that primarily supports long missions, the position of the sun is to be updated regularly. Also, because the pilot will be primarily flying visual bombing runs, sunlight-angle effects are considered important.

3.7.1.4.1 Sun. The sun's appearance and illumination characteristics shall be simulated. The position of the sun shall be updated as often as necessary to ensure that the angle between the true line of sight to the sun's position as specified in the approved design criteria and the simulated line of sight to the sun is less than one degree, and that the sun appears to move smoothly across the visual scene. The sun shall also assume a stationary position corresponding to a selected time of the day upon command. The appearance of objects in the visible spectrum shall change with the simulated position of the sun in accordance with the requirements of this specification. Sun-cast shadows in the visual scene may correspond to the sun's position.

4.2.1.7.1.4.1 Verification of Sun. This requirement shall be verified by demonstration. The position of the sun shall be verified by demonstration using the simulator's cockpit visual system. The change in the appearance of objects caused by the sun in the visible spectrum shall be verified by demonstration using the simulator's cockpit visual system.

Example 2. For a device that primarily supports short daytime transport missions, it may not be necessary for the simulated position of the sun to be dynamic. Similarly, it might not be necessary to simulate changes in appearance of objects in any spectrum.

3.7.1.4.1 Sun. The sun's appearance and illumination characteristics shall be simulated. The position of the sun shall remain fixed at a point consistent with the shadows appearing on displayed texture maps during simulation of daylight conditions.

4.2.1.7.1.4.1 Verification of Sun. This requirement shall be verified by demonstration. The position of the sun shall be verified by demonstration using the simulator's cockpit visual system.

Example 3. For a short mission strike-training simulator, a moving sun is not necessary, but it is important to have the sun in the approximate area for the time of day, day of year, and location of the simulated mission. In addition, infrared sensing air-to-ground missiles may be affected by different infrared reflectivities caused by a particular sun position. Therefore the infrared as well as visible reflections should be correlated to the time period of the mission.

3.7.1.4.1 Sun. The sun's appearance and illumination characteristics shall be simulated. The position of the sun shall be updated to represent morning, noon, and afternoon lighting conditions. The morning sun shall be positioned as it would be seen at 0800 on the day and at the geographical location corresponding to the mission exercise. The midday and afternoon sun shall be positioned at 1200 and 1600, respectively, in the same manner. The sun shall assume a stationary position corresponding to a selected time of the day upon command. The appearance of objects in the visible and infrared spectra shall change with the simulated position of the sun in accordance with the requirements of this specification. Sun-cast shadows in the visual scene may correspond to the sun's position.

4.2.1.7.1.4.1 Verification of Sun. This requirement shall be verified by demonstration and analysis. The position of the sun shall be verified by demonstration using the simulator's cockpit visual system. The change in the appearance of objects caused by the sun in the visible spectrum shall be verified by demonstration using the cockpit's visual system. The change in the appearance of objects caused by the sun in the infrared spectrum shall be verified by demonstration and analysis using a realtime monitor displaying infrared reflectivity levels of such objects.

3.7.1.4.2 Moon. The moon's appearance and illumination characteristics shall be simulated. __1__. The phase of the moon shall __2__. (3)The moon shall (also) assume a selected stationary position and phase upon command. (4)The appearance of objects in the __4a__ (spectrum/spectra) shall change with the simulated position of the moon in accordance with the requirements of this specification. (5)Moon-cast shadows in the visual scene (shall/may) correspond to the moon's position.

4.2.1.7.1.4.2 Verification of Moon. This requirement shall be verified by demonstration (6)and analysis. The position and phase of the moon shall be verified by demonstration using __7__. (8)The change in the appearance of objects caused by the moon in the __8a__ (spectrum/spectra) shall be verified by demonstration (9)and analysis using __10__. (11)The correct correspondence of cast shadows to moon position shall be demonstrated using __11a__.

RATIONALE

Requirements Guidance:

1. Blank (1) should describe whether the moon's position will be mobile (appear to move across the sky) or whether it will remain in a stationary position throughout a simulated mission. Whether the position of the moon is mobile or stationary depends on whether the primary function of the simulator will be to simulate long (more than 3 hour) or short (less than 3 hour) missions, and the importance of updated moon position to the application. In extended length missions, the position of the moon may be updated on a regular basis. In short missions, it may not be necessary to show the moon moving as the night progresses, but the moon should hold a position representative of the approximate time period and location at which the mission is flown.

If the moon is to remain stationary and time independent, insert the following sentence in blank (1): "The image of the moon shall remain stationary with respect to the observer at the commanded azimuth and elevation."

If the moon is to remain stationary but time dependent, insert the following sentence in blank (1): "The image of the moon shall remain stationary throughout the mission, and hold the position at which it would be seen at the time, day, and geographical location of the start of the mission."

If the moon is to be implemented as a moving object, insert the following sentence in blank (1): "The position of the moon shall be updated as often as necessary to ensure that the angle between the true line of sight to the moon's position as specified in the approved design criteria and the simulated line of sight to the moon is less than __1b__, and that the moon appears to move smoothly across the visual scene."

where blank (1b) is a tolerance angle with units such as degrees, radians, or arc-seconds.

2. Blank (2) should describe the moon-phase requirement. Possibilities include, "always be full/first-quarter/half/second quarter", "be commanded", "be representative of that seen at the time of starting the mission", or "vary in time in accordance with the approved data".

3. Delete the sentence following (3) if commanded moon position is not required, or if this sentence is inconsistent with the tailored requirement (e.g., cases such as Example 2). Otherwise tailor the sentence to be consistent with the requirement established in blanks (1) and (2).

4. If there is no requirement for the appearance of objects to be affected by the position of the moon, delete the sentence following (4). Otherwise retain this sentence, and fill in blank (4a) with the electromagnetic spectrum or spectra to be affected by changes in the moon's position. These could include the visible, infrared or other relevant electromagnetic spectra that are required to reflect effects of the moon's position.

5. If the sentence following (5) is inconsistent with the tailored requirements, delete it. Otherwise tailor the sentence following (5) to specify whether moon-cast shadows "shall" or "may" correspond to the simulated moon position. This sentence is intended as a qualification and clarification regarding the illumination characteristics that are to be simulated. A requirement for correlated moon-cast shadow simulation should be avoided unless there is a compelling training or mission rehearsal requirement.

Verification Guidance:

6. If sentence (4) is deleted (i.e., if there is no requirement for the appearance of objects to change as a function of the moon's position) or if changes in the moon's position affect only the visible spectrum, delete the phrase "and analysis" following (6).

7. In blank (7), specify the name of the appropriate visual system(s).

8. If sentence (4) is deleted, delete the sentence following (8). Otherwise retain this sentence and copy the contents of blank (4a) into blank (8a).

9. If change in the moon's position affects only the visible spectrum, delete the phrase "and analysis" following (9).

10. If sentence (4) is deleted or if changes in the moon's position affect only the visible spectrum, blank (10) can simply be filled in with the name of the appropriate visual system(s). If the simulation is to include effects in non-visible spectra as well, an analysis should be performed using a realtime data display linked to the running simulator; the display approach and the data to be analyzed should be specified in blank (10).

11. If the sentence following (5) was deleted or if moon-cast shadows need not (i.e., "may") correspond to the moon's position, delete the sentence following (11). Otherwise specify the name of the appropriate display system(s) in blank (11a).

EXAMPLES
Example 1. For a simulator that primarily supports long missions, the position of the moon is to be updated regularly. Also, because the pilot will be primarily flying visual bombing runs, moonlight-angle effects are considered important:

3.7.1.4.2 Moon. The moon's appearance and illumination characteristics shall be simulated. The position of the moon shall be updated as often as necessary to ensure that the angle between the true line of sight to the moon's position as specified in the approved design criteria and the simulated line of sight to the moon is less than one degree, and that the moon appears to move smoothly across the visual scene. The phase of the moon shall be representative of that seen at the time of starting the mission. The moon shall also assume a selected stationary position and phase upon command. The appearance of objects in the visible spectrum shall change with the simulated position of the moon in accordance with the requirements of this specification. Moon-cast shadows in the visual scene may correspond to the moon's position.

4.2.1.7.1.4.2 Verification of Moon. This requirement shall be verified by demonstration. The position and phase of the moon shall be verified by demonstration using the simulator's cockpit visual system. The change in the appearance of objects caused by the moon in the visible spectrum shall be verified by demonstration using the simulator's cockpit visual system.

Example 2. For a device that primarily supports short night-time transport missions, it may not be necessary for the simulated position of the moon to be dynamic. Similarly, it might not be necessary to simulate changes in appearance of objects in any spectrum.

3.7.1.4.2 Moon. The moon's appearance and illumination characteristics shall be simulated. The image of the moon shall remain stationary with respect to the observer at the commanded azimuth and elevation. The phase of the moon shall be commanded. Moon-cast shadows in the visual scene may correspond to the moon's position.

4.2.1.7.1.4.2 Verification of Moon. This requirement shall be verified by demonstration. The position and phase of the moon shall be verified by demonstration using the simulator's cockpit visual system.

Example 3. For a short mission strike-training simulator, a moving moon is not necessary, but it is important to have the moon in the approximate area for the time of night, day of year, and location of the simulated mission. In addition, night vision goggles may be affected by the different positions and phases of the moon. Therefore the near-infrared as well as visible reflections should be correlated to the time period of the mission.

3.7.1.4.2 Moon. The moon's appearance and illumination characteristics shall be simulated. The image of the moon shall remain stationary throughout the mission, and hold the position at which it would be seen at the time, day, and geographical location of the start of the mission. The phase of the moon shall be representative of that seen at the time of starting the mission. The appearance of objects in the visible and infrared spectra shall change with the simulated position of the moon in accordance with the requirements of this specification. Moon-cast shadows in the visual scene shall correspond to the moon's position.

4.2.1.7.1.4.2 Verification of Moon. This requirement shall be verified by demonstration and analysis. The position and phase of the moon shall be verified by demonstration using the simulator's cockpit visual system. The change in the appearance of objects caused by the moon in the visible spectrum shall be verified by demonstration using the simulator's cockpit visual system. The change in the appearance of objects caused by the moon in the infrared spectrum shall be verified by demonstration and analysis using a realtime monitor displaying infrared reflectivity levels of the objects. The correct correspondence of cast shadows to moon position shall be demonstrated using night vision goggles to observe the cockpit visual system display.

3.7.1.4.3 Planets. The appearance and illumination characteristics of the following planets shall be simulated: __1__. The position of the planet(s) shall be updated as often as necessary to ensure that the angle between the true line of sight to a planet's position as specified in the approved design criteria and the simulated line of sight to the planet is less than __2__, and that the planet(s) appear(s) to move smoothly across the visual scene.

4.2.1.7.1.4.3 Verification of Planets. This requirement shall be verified by demonstration and analysis. The position of each specified planet shall be verified by demonstration using the visual system and analysis of __3__.

RATIONALE

Requirements Guidance:

1. Blank (1) should list the names of the planet(s) required in the simulator to support navigation exercises.

2. Blank (2) is a tolerance angle with units such as degrees, radians, or arc-seconds.

Verification Guidance:

3. Blank (3) should be filled in with an appropriate method of analysis, e.g., "the output of a realtime digital data display, independent from the simulator that shows the position of each planet".

EXAMPLES
This example describes the requirement for a simulator that displays the planets Mercury, Venus, Mars, Jupiter, and Saturn, accurate to 0.5 degrees:

3.7.1.4.3 Planets. The appearance and illumination characteristics of the following planets shall be simulated: Mercury, Venus, Mars, Jupiter, and Saturn. The position of the planets shall be updated as often as necessary to ensure that the angle between the true line of sight to a planet's position as specified in the approved design criteria and the simulated line of sight to the planet is less than 0.5 degree, and that the planets appear to move smoothly across the visual scene.

4.2.1.7.1.4.3 Verification of Planets. This requirement shall be verified by demonstration and analysis. The position of each specified planet shall be verified by demonstration using the visual system and analysis of the output of a realtime digital data monitor that shows the position of each planet.

3.7.1.4.4 Stars. __1__.

4.2.1.7.1.4.4 Verification of Stars. This requirement shall be verified by demonstration (2)and analysis. (3)The position of each specified star shall be verified by demonstration using the visual system and analysis of __3a__.

RATIONALE

Requirements Guidance:

1. Blank (1) should be filled in with one of the three following paragraphs:

"The appearance and illumination characteristics of the following star constellations and single stars shall be simulated: __1a__. The position of the stars shall be updated as often as necessary to ensure that the angle between the true line of sight to a given star's position as specified in the approved design criteria and the simulated line of sight to the star is less than __1b__, and that the stars appear to move smoothly across the visual scene."

where blank (1a) is a list of constellations and/or single stars and blank (1b) is a tolerance angle with units such as degrees, radians or, arc-seconds.

"The appearance and illumination characteristics of the following star constellations and single stars shall be simulated: __1a__. The position of the stars shall remain stationary throughout the mission, and hold positions representative of the positions at which they would be seen at the time, day, and geographical location of the start of the mission."

where blank (1a) is a list of constellations and/or single stars.

"The appearance of a star field shall be simulated to add texture to the night sky. The stars need not represent positions of stars in the real world. The star field (shall/may) move across the sky to represent the rotation of the earth as time elapses."

Verification Guidance:

2. If simulated star positions are not required to correspond to their real-world positions, delete the phrase "and analysis" following (2).

3. If simulated star positions are not required to correspond to their real-world positions, delete the sentence following (3). Otherwise, retain the sentence following (3) and fill blank (3a) with an appropriate

method of analysis, e.g., "the output of a realtime digital data display, independent from the simulator that shows the position of each required star".

EXAMPLES

Example 1. This example is for a simulator that will use only the North Star as a navigational aid. The simulator might be used for long distance transport missions where the crew might use the North Star as a backup navigational aid.

3.7.1.4.4 Stars. The appearance and illumination characteristics of the following star shall be simulated: Polaris (the North Star). The position of the star shall be updated as often as necessary to ensure that the angle between the true line of sight to a given star's position as specified in the approved design criteria and the simulated line of sight to the star is less than 0.5 degree, and that the star appears to move smoothly across the visual scene

4.2.1.7.1.4.4 Verification of Stars. This requirement shall be verified by demonstration and analysis. The position of star shall be verified by demonstration using the visual system and analysis of the output of a realtime digital data monitor that shows the position of the star.

Example 2. This example is for a simulator that shall simulate all of the constellations described in the approved design criteria. The constellations hold a fixed position in the sky during the course of the mission. This simulator would be used for short night missions.

3.7.1.4.4 Stars. The appearance and illumination characteristics of the following star constellations shall be simulated: all constellations as detailed in the approved design criteria. The position of the stars shall remain stationary throughout the mission, and hold positions representative of the positions at which they would be seen at the time, day, and geographical location of the start of the mission.

4.2.1.7.1.4.4 Verification of Stars. This requirement shall be verified by demonstration and analysis. The position of each specified star shall be verified by demonstration using the visual system and analysis of the output of a realtime digital data monitor that shows each star's position.

Example 3. This example is for a simulator that generates a random field of stars for the purpose of sky texture only. The stars may remain stationary throughout the mission. This simulator might be used for short air intercept missions.

3.7.1.4.4 Stars. The appearance of a star field shall be simulated to add texture to the night sky. The stars need not represent positions of stars in the real world. The star field may move across the sky to represent the rotation of the earth as time elapses.

4.2.1.7.1.4.4 Verification of Stars. This requirement shall be verified by demonstration and analysis.

3.7.1.5 Entities. Entities shall represent individual elements in the following parts of the synthetic environment: (1)

a. Combat Systems which support or oppose the simulated aircraft.

1. Individual fighter, bomber, and attack aircraft.

2. Individual elements of air defense networks. Each element shall include the applicable vehicle, sensors, weapons, and command, control, communications, computers, and intelligence systems located with the individual element.

3. Individual elements of ground forces. Each element shall include the applicable vehicle, sensors, weapons, and command, control, communications, computers, and intelligence systems located with the individual element.

4. Individual elements of naval forces. Each element shall include the applicable vehicle, sensors, weapons, and command, control, communications, computers, and intelligence systems located with the individual element.

b. Combat support systems which support those forces supporting and opposing the simulated aircraft.

1. Air refueling aircraft.

2. AWACS, JSTARS, and similar standoff support aircraft.

3. EF-111A, EA-6B, and similar jammer aircraft.

4. C4I aircraft and stations associated with the items listed in a above.

c. Navigation systems.

1. Global Positioning System.

2. Airways.

3. LORAN.

4. OMEGA.

d. Air Traffic Control Systems.

1. TACAN Stations.

2. Air Traffic Control Centers.

3. ILS at airfields.

e. Weapons and expendables launched by the simulated air vehicle.

Each entity shall represent a single system as listed in paragraph 3.7.1.5.6. Each entity consists of an entity platform and the following as required:

a. Entity emitters.

b. Entity sensors.

c. Entity operators.

d. Other aggregated entities.

4.2.1.7.1.5 Verification of Entities. Verification of this requirement is not applicable.

RATIONALE

Entities represent objects and personnel in the environment which are not permanently fixed to the earth's surface, whose behavior cannot be predicted explicitly from physical laws, or which could be expected to exhibit variable behavior over a simulator mission. An entity is an individual vehicle, fixed weapon system site, radio station, etc. Entities are combined to produce larger parts of the environment such as air defense networks, hostile ground forces, etc. Note, however, that a single entity must

represent a complete weapons system (e.g., an aircraft with its associated radars and missiles). Entities may deaggregate additional entities (e.g., an aircraft carrier launches aircraft or an aircraft fires missiles).

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES

Example 1. A primary training aircraft with no combat simulation.

3.7.1.5 Entities. Entities shall represent individual elements in the following parts of the synthetic environment:

a. Navigation systems.

1. Global Positioning System.

2. Airways.

b. Air Traffic Control Systems.

1. TACAN Stations.

2. Air Traffic Control Centers.

3. ILS at airfields.

Each entity shall represent a single system as listed in paragraph 3.7.1.5.6. Each entity shall consist of an entity platform and the following as required.

a. Entity emitter.

b. Entity operator.

Example 2. An air-to-air combat part task trainer.

3.7.1.5 Entities. Entities shall represent individual elements in the following parts of the synthetic environment:

a. Combat Systems which support or oppose the simulated aircraft.

1. Individual fighter, bomber, and attack aircraft.

2. Individual elements of air defense networks. Each element shall include the applicable vehicle, sensors, weapons, and command, control, communications, computers, and intelligence systems located with the individual element.

b. Combat support systems which support those forces supporting and opposing the simulated aircraft.

1. AWACS, JSTARS, and similar standoff support aircraft.

2. EF-111A, EA-6B, and similar jammer aircraft.

3. C4I aircraft and stations associated with the items listed in a above.

c. Weapons launched and cargo or expendables dropped by the simulated air vehicle.

Each entity shall represent a single system as listed in paragraph 3.7.1.5.6. Each entity consists of an entity platform and the following as required:

a. Entity emitters.

b. Entity sensors.

c. Entity operators.

d. Other aggregated entities.

3.7.1.5.1 Entity Platforms. (1)Entity platforms represent the vehicle associated with a mobile entity and any fixed structures associated with non-mobile entities. Entity platforms are defined in terms of their entity platform signatures and their dynamics. The entity platform signature is based on size, shape, and material composition of the system represented by the entity.

4.2.1.7.1.5.1 Verification of Entity Platforms. Verification of this requirement is not applicable.

RATIONALE
The subparagraphs define the appearance of entities on passive sensors and visual systems. They define this only to the extent it is based on size, shape, and material composition of the system represented by the entity.

Requirements Guidance:

1. *Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.*

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.1 Entity Platforms. Entity platforms represent any fixed structures and locations associated with entities. Entity platforms are defined in terms of their entity platform signatures and their dynamics.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.1 Entity Platforms. Entity platforms represent the vehicle associated with a mobile entity and any fixed structures associated with non-mobile entities. Entity platforms are defined in terms of their entity platform signatures and their dynamics. The entity platform signature is based on size, shape, and material composition of the system represented by the entity.

3.7.1.5.1.1 Entity Platform Signatures. The following definitions shall apply to the entity platform signature of each entity required by paragraph 3.7.1.5.6: (1)

a. Immutable - The entity represents a system that reflects light and radiates stored energy. The signature does not change during a simulator exercise.

b. Mutable - The entity represents a system that reflects light and radiates stored energy. The signature changes upon command during a simulation exercise.

c. Null - No entity platform signature is required.

4.2.1.7.1.5.1.1 Verification of Entity Platform Signatures. Verification of this requirement is not applicable.

RATIONALE

Entity platform signatures are provided for use on visual, radar and infrared systems on simulators. Some examples are:

a. Immutable - Immutable entity platform signatures include vehicles, ships temporary buildings, etc. They may be dynamic in that their position and orientation can change continuously during the exercise, but they do not change shape and parts of the entity do not move. They are provided primarily for presentation on sensors and weapons scoring.

b. Mutable - Mutable passive entities include such things as tanks whose turrets can turn, aircraft with movable control surfaces, or lights that can be commanded to be on or off. An entity operator (see 3.7.1.5.4) or entity dynamics (see 3.7.1.5.2) will often be required to produce the signature mutation.

c. Null - the entity platform signature cannot be seen by the simulated aircraft. Null entity platform signatures could represent systems that are camouflaged, which are already included in the geographic data base, or which are not significant in a particular simulator (e.g., if there is no visual system).

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES

Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.1.1 Entity Platform Signatures. Entity platform signatures are not required.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.1.1 Entity Platform Signatures. The following definitions shall apply to the entity platform signature of each entity required by paragraph 3.7.1.5.6:

a. Immutable - The entity represents a system that reflects light and radiates stored energy. The signature does not change during a simulator exercise.

b. Mutable - The entity represents a system that reflects light and radiates stored energy. The signature changes upon command during a simulation exercise.

c. Null - No entity platform signature is required.

3.7.1.5.1.2 Entity Platform Signature Fidelity. The following definitions shall apply as the minimum required levels of fidelity required for each entity required by paragraph 3.7.1.5.6: (1)

a. Replicated - Provides signatures identical to that of the system being simulated to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria and physical laws.

1) Size, shape and color and variations due to position of the simulated air vehicle.

2) Vehicle markings and lights

3) Position and movement of vehicle parts (mutable entity platform signatures only)

4) Vehicle exhaust plumes

5) Changes in signature due to damage (mutable entity platform signatures only)

6) Changes in signature due entity deaggregation (mutable entity platform signatures only)

7) Other perceptible signature characteristics

Replicated fidelity applies to a specific system, i.e., type of aircraft (e.g., Flogger A), unique ship (e.g., USS John F. Kennedy), type of vehicle (e.g., M1A1 tank), type of weapon (e.g., AIM 120) or type of unit (e.g., Soviet Army platoon).

b. Generically replicated - Provides signatures typical of the system being simulated to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria. Subparagraphs of **a** apply. Generically replicated refers to typical systems (e.g., aircraft Soviet fighter), class of ship (e.g., US aircraft carrier), class of vehicle (e.g., US tank), class of weapon (e.g., air-to-air missile), or class of unit (e.g., infantry). Actual intelligence data for a representative system may be used.

c. Partially replicated - Some of the subparagraphs listed in a are not required.

d. Approximated - Only greatly simplified representation is required.

4.2.1.7.1.5.1.2 Verification of Entity Platform Signature Fidelity. Verification of this requirement is not applicable.

RATIONALE
Fidelity is very subjective and difficult to describe. The specification defines grades of fidelity. Clearly the higher the fidelity grade, the closer the operation to the real world. Some judgment will be required in evaluating fidelity in all cases.

a. "Replicated" tries to match the real world to the extent that it can be defined by design criteria.

b. "Generically replicated" provides systems typical of the real world that may not exactly match any single real world system.

c. "Partially replicated" and "approximated" means that fidelity is deliberately reduced.

Replicated and generically replicated systems should require the same amount of computer processing. Generically replicated systems could result in less data storage, and will certainly reduce the amount of design criteria research.

The degree of partial replication and approximation should be defined in paragraph 3.7.1.5.6.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.1.2 Entity Platform Signature Fidelity. This requirement is not applicable.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.1.2 Entity Platform Signature Fidelity. The following definitions shall apply as the minimum required levels of fidelity required for each entity required by paragraph 3.7.1.5.6:

a. Replicated - Provides signatures identical to that of the system being simulated to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria and physical laws.

1) Size, shape and color and variations due to position of the simulated air vehicle.

2) Vehicle markings and lights

3) Position and movement of vehicle parts (mutable entity platform signatures only)

4) Changes in signature due to damage (mutable entity platform signatures only)

5) Changes in signature due entity deaggregation (mutable entity platform signatures only)

Replicated fidelity applies to a specific system, i.e., type of aircraft (e.g., Flogger A).

b. Generically replicated - Provides signatures typical of the system being simulated to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria. Subparagraphs of **a** apply. Generically replicated refers to typical systems (e.g., aircraft Soviet fighter). Actual intelligence data for a representative system may be used.

c. Partially replicated - Some of the subparagraphs listed in a are not required.

d. Approximated - Only greatly simplified representation is required.

3.7.1.5.1.3 Entity Platform Dynamics Control. The following definitions shall apply to the degree of position and orientation control for each entity required by paragraph 3.7.1.5.6: (1)

a. Immobile - The entity may be commanded to a fixed position and orientation by the simulator mission script. It instantly moves to the commanded position and orientation and remains fixed until a new position or orientation is commanded.

b. Mobile - The entity may be assigned an initial position and velocity by the simulator mission script; it moves upon command with the fidelity required by paragraph 3.7.1.5.6.

4.2.1.7.1.5.1.3 Verification of Entity Platform Dynamics Control. Verification of this requirement is not applicable.

RATIONALE

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.1.3 Entity Platform Dynamics Control. Each entity may be commanded to a fixed position and orientation by the simulator mission script. It instantly moves to the commanded position and orientation

and remains fixed until a new position or orientation is commanded. Satellites associated with the Global Positioning System shall be assumed to provide optimal coverage of the simulator gaming area.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.1.3 Entity Platform Dynamics Control. The following definitions shall apply to the degree of position and orientation control for each entity required by paragraph 3.7.1.5.6:

a. Immobile - The entity may be commanded to a fixed position and orientation by the simulator mission script. It instantly moves to the commanded position and orientation and remains fixed until a new position or orientation is commanded.

b. Mobile - The entity may be assigned an initial position and velocity by the simulator mission script; it moves upon command with the fidelity required by paragraph 3.7.1.5.6.

3.7.1.5.1.4 Entity Platform Dynamics Fidelity. The following definitions shall apply as the minimum levels of entity platform dynamics' fidelity required for each mobile entity platform required by paragraph 3.7.1.5.6: (1)

a. Replicated - The mobile entity platform representing land or sea based vehicles shall be constrained to move on the surface of the earth. Constraints on land, sea or air vehicle performance (e.g., aerodynamics, fuel load, weapon load, constrained to water of a certain depth, constrained to earth's surface, constrained to roads, constrained to railroad tracks, etc.) shall be simulated in accordance with design criteria and physical laws.

b. Partially replicated - Mobile entity platform representing land or sea based vehicles shall be constrained to move on the surface of the earth; vehicle performance of the system represented by the entity is not completely modeled.

c. Approximated - Mobile entity platforms representing vehicles shall move as commanded without regard to physical constraints or the simulated earth surface.

4.2.1.7.1.5.1.4 Verification of Entity Platform Dynamics Fidelity. Verification of this requirement is not applicable.

RATIONALE

This paragraph defines grades of fidelity for the positioning and movement of entities. Fidelity is very subjective and difficult to describe. Clearly the higher the fidelity grade the closer the operation to the real world. Some judgment will be required in evaluating fidelity in all cases. Fully realistic modeling, as required by "replicated" dynamics, has not been extensively used in training applications but may be appropriate for very high-fidelity applications. "Partially replicated" and "approximated" dynamics are much more common. It is important that the fidelity of entity positioning and movement be carefully described. When "partially replicated" or "approximated" is called out, the degree of partial replication or approximation must be defined in paragraph 3.7.1.5.6.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES

Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5. In this case, this paragraph should be deleted.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.1.4 Entity Platform Dynamics Fidelity. The following definitions shall apply as the minimum levels of entity platform dynamics' fidelity required for each mobile entity platform required by paragraph 3.7.1.5.6:

a. Replicated - The mobile entity platform representing land or sea based vehicles shall be constrained to move on the surface of the earth. Constraints on land, sea or air vehicle performance (e.g., aerodynamics, fuel load, weapon load, etc.) shall be simulated in accordance with design criteria and physical laws.

b. Partially replicated - Vehicle performance of the system represented by the entity is not completely modeled.

c. Approximated - Mobile entity platforms representing vehicles shall move as commanded without regard to physical constraints or the simulated earth surface.

3.7.1.5.2 Entity Emitters. (1)Entity emitters represent those portions of systems represented by entities that deliberately emit electromagnetic energy. Entity emitters are defined in terms of emissions and emitter fidelity.

4.2.1.7.1.5.2 Verification of Entity Emitters. Verification of this requirement is not applicable.

RATIONALE
Entity emitters represent radars, jammers, radios, etc. They are located on the entity platform. They represent deliberate active emissions.

Requirements Guidance:

1. *Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.*

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.2 Entity Emitters. Entity emitters represent those portions of systems represented by entities that deliberately emit electromagnetic energy. Entity emitters are defined in terms of emissions and emitter fidelity.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.2 Entity Emitters. Entity emitters represent those portions of systems represented by entities that deliberately emit electromagnetic energy. Entity emitters are defined in terms of emissions and emitter fidelity.

3.7.1.5.2.1 Emissions. The following definitions shall apply to each emitter of each entity emitter required by paragraph 3.7.1.5.6: (1)

a. Mutable - The emissions change upon command during a simulation exercise.

b. Immutable - The emissions remain constant, or vary in a periodic or random manner throughout a simulator exercise.

c. Null - No emitter is required.

4.2.1.7.1.5.2.1 Verification of Emissions. Verification of this requirement is not applicable.

RATIONALE
Mutable emissions represent fire control radars and other similar systems which must change important emission characteristics (frequency, pulse repetition frequency, antenna scan, etc.) either as a function of the situation in a simulator exercise or via instructor control. For example, a particular radar may change from search to track in response to countermeasures by the simulated air vehicle. Immutable emissions represent radio stations that broadcast a constant signal, search radars that scan in a constant pattern, etc. Null emissions represent systems with no active emissions.

Requirements Guidance:

1. *Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.*

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.2.1 Emissions. The emissions remain constant or vary in a periodic or random manner throughout a simulator exercise.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.2.1 Emissions. The following definitions shall apply to each emitter of each entity emitter required by paragraph 3.7.1.5.6:

a. Mutable - The emissions change upon command during a simulation exercise.

b. Immutable - The emissions remain constant, or vary in a periodic or random manner throughout a simulator exercise.

c. Null - No emitter is required.

3.7.1.5.2.2 Emitter Fidelity. The following definitions shall apply as the minimum levels of emitter fidelity required for each entity emitter required by paragraph 3.7.1.5.6: (1)

a. Replicated - Electronic characteristics of the particular system are represented to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria. Replicated applies to a specific system (e.g., Pat Hand).

b. Generically replicated - Electronic characteristics typical of the system are represented to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria. Generically replicated applies to a class of systems (e.g., Soviet search radars, AM radio stations, etc.). Actual intelligence data for a representative system may be used.

c. Approximated - Electronic characteristics are simplified or not required.

4.2.1.7.1.5.2.2 Verification of Emitter Fidelity. Verification of this requirement is not applicable.

RATIONALE
Fidelity is very subjective and difficult to describe. The specification defines grades of fidelity. Clearly the higher the fidelity grade, the closer the match to the real world. Some judgment will be required in evaluating fidelity in all cases. The degree of approximation should be described in paragraph 3.7.1.5.6. Past programs have usually required replicated fidelity.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.2.2 Emitter Fidelity. The following definitions shall apply as the minimum levels of emitter fidelity required for each entity emitter required by paragraph 3.7.1.5.6:

a. Replicated - Electronic characteristics of the particular system are represented to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria. Replicated applies to a specific system (e.g., the ILS on Runway 30 at Mather AFB).

b. Approximated - Electronic characteristics are simplified or not required.

Example 2 An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.2.2 Emitter Fidelity. The following definitions shall apply as the minimum levels of emitter fidelity required for each entity emitter required by paragraph 3.7.1.5.6:

a. Replicated - Electronic characteristics of the particular system are represented to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria. Replicated applies to a specific system (e.g., Pat Hand).

b. Generically replicated - Electronic characteristics typical of the system are represented to the extent that performance can be perceived by crew members in the simulated vehicle as defined by design criteria. Generically replicated applies to a class of systems (e.g., Soviet search radars, AM radio stations, etc.). Actual intelligence data for a representative system may be used.

c. Approximated - Electronic characteristics are simplified or not required.

3.7.1.5.3 Entity Sensors. (1)Entity sensors represent those portions of the system represented by an entity that can determine and process information about the simulated aircraft, other entities in the environment, and other parts of the synthetic environment. Entity sensor requirements are defined in terms of sensor fidelity and interconnectivity.

4.2.1.7.1.5.3 Verification of Entity Sensors. Verification of this requirement is not applicable.

RATIONALE
Sensors differ from emitters in a simulation in that sensors are the means by which an entity determines information about the simulated air vehicle and the synthetic environment (e.g., avionics receivers and human eyeballs), while emitters present information that can be sensed by the simulated aircraft. It is important to note that a single system such as a radar may be represented by both an emitter and a sensor.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.3 Entity Sensors. This requirement is not applicable.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.3 Entity Sensors. Entity sensors represent those portions of the system represented by an entity that can determine and process information about the simulated aircraft, other entities in the environment, and other parts of the synthetic environment. Entity sensor requirements are defined in terms of sensor fidelity and interconnectivity.

3.7.1.5.3.1 Sensor Fidelity. The following definitions shall apply as the minimum levels of entity sensor fidelity required for each entity sensor required by paragraph 3.7.1.5.6: (1)

a. Replicated - All the sensing functions of the entity are represented as defined by design criteria and affected by the laws of physics. This includes:

1. States of the simulated aircraft and entities.

2. Cross-sectional effects of the simulated aircraft and other entities.

3. Its own emissions, emissions of other entities, and emission of the simulated aircraft.

4. Countermeasures applied by the simulated aircraft and other entities.

5. Interaction of 1-4 above with other parts of the synthetic environment (e.g., topography, cultural features, meteorology, etc.).

b. Partially replicated - some of the factors in a.1 through a.5 above are not required.

c. Null - the sensor need not be represented.

4.2.1.7.1.5.3.1 Verification of Sensor Fidelity. Verification of this requirement is not applicable.

RATIONALE

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5. The paragraph should be deleted.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.3.1 Sensor Fidelity. The following definitions shall apply as the minimum levels of entity sensor fidelity required for each entity sensor required by paragraph 3.7.1.5.6:

a. Replicated - All the sensing functions of the entity are represented as defined by design criteria and affected by the laws of physics. This includes:

1. States of the simulated aircraft and entities.

2. Cross-sectional effects of the simulated aircraft and other entities.

3. Its own emissions, emissions of other entities, and emission of the simulated aircraft.

4. Countermeasures applied by the simulated aircraft and other entities.

5. Interaction of 1-4 above with other parts of the synthetic environment (e.g., topography, cultural features, meteorology, etc.).

b. Partially replicated - some of the factors in a.1 through a.5 above are not required.

c. Null - the sensor need not be represented.

3.7.1.5.3.2 Interconnectivity. The following definitions apply to interconnectivity of the entities required by paragraph 3.7.1.5.6: (1)

a. Fully networked - The entities are interconnected to represent a full-up, specific, real-world air defense or air traffic control network. The entity sends all information to other entities on the simulated network that the real system sends to the real air defense network. The other entities on the simulated network send all information to the entity that is available to the real system on the real network. The time delays in information processing match the real world.

b. Interconnected - Information is exchanged among entities to represent typical air defense or air traffic control networks. The entity sends all information to other entities on the simulated network that the real system would send to a real air defense network. The other entities on the simulated network send all information to the entity that is typically available to the real system on the real network. The time delays in information processing are typical of the real world.

c. Limited - Information is exchanged among entities representing the state of the simulated aircraft and other entities in the environment. Time delays in information processing are typical of the real world.

d. Non-interconnected - no information is exchanged with other entities.

4.2.1.7.1.5.3.2 Verification of Interconnectivity. Verification of this requirement is not applicable.

RATIONALE
Interconnectivity is the degree to which entities are interconnected to represent command and control or other networks. Degree of interconnectivity is very subjective and difficult to describe. The specification defines grades of interconnectivity. Clearly the higher the interconnectivity grade, the closer the match to the real world. Some judgment will be required in evaluating interconnectivity in all cases.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5. The paragraph should be deleted.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.3.2 Interconnectivity. The following definitions apply to interconnectivity of the entities required by paragraph 3.7.1.5.6:

a. Interconnected - Information is exchanged among entities to represent typical air defense or air traffic control networks. The entity sends all information to other entities on the simulated network that the real system would send to a real air defense network. The other entities on the simulated network

send all information to the entity that is typically available to the real system on the real network. The time delays in information processing are typical of the real world.

b. Non-interconnected - no information is exchanged with other entities.

3.7.1.5.4 Entity Operation. The following definitions apply to operation of the entities required by paragraph 3.7.1.5.6: (1)

a. Intelligent - The entity automatically responds to all information that can be determined through its sensor(s). The response follows the doctrine, tactics, and procedures of the nation who operates the system represented by the entity as well as available design criteria. The response of the system is based on the overall situation to the extent required by this specification. For entities representing manned systems, the response is based on the mental and physical capacity of typical system operators.

b. Algorithmic - The entity automatically responds to all information that can be determined through its sensor(s). The response is typical of the tactics and procedures of the nation who operates the system represented by the entity as well as available design criteria. The response of the system is based on the overall situation to the extent required by this specification.

c. Simplified - The entity responds to the simulated air vehicle based on its current position, velocity, and electronic emissions. The response of the system is based on the overall situation to the extent required by this specification.

d. Non-intelligent - The entity does not respond to the simulated air vehicle or the overall situation.

e. Interactive master - The entity can command the performance of entities representing the same system for other stations or simulators in interactive mode operation.

In addition, entities shall be commanded in accordance with paragraph 3.7.4. If such commands conflict with other required operation, the commands shall override.

4.2.1.7.1.5.4 Verification of Entity Operation. Verification of this requirement is not applicable.

RATIONALE

The requirement for modeling the operation of systems is very subjective and difficult to describe. The specification defines grades of intelligence. Clearly the higher the intelligence grade, the closer the operation to the real world with real human operators in the loop. Some judgment will be required in evaluating intelligence in all cases. The intent of this paragraph is to describe the 'intelligence" built into a given entity.

a. Intelligent means the closest practical representation of the real world. It is intended to model a single system that operates as part of a total air traffic control system, air defense system, etc. Response to the total situation is based principally on the requirements for interconnectivity and detection. The model considers national doctrine, tactics, and procedures to the extent they are defined by source data (e.g., intelligence) and the variation in skill level of potential operators.

b. Algorithmic is a simplified representation for entity intelligence. It is intended to model a single system that operates as part of a total air traffic control system, air defense system, etc. Response to the total situation is based principally on the requirements for interconnectivity and detection. Responses may be typical or estimates based on source data. Operator skill level is assumed to be fixed at a normal level.

c. Simplified is a lower-fidelity representation. Responses are based only on the present state of the ownship. Response to interconnectivity and detection is limited to mode changes.

d. Non-intelligent entities do not respond to the simulated air vehicle or the environment.

In most simulators the operation of electronic combat systems has been represented at the algorithmic or simplified level. Air traffic control systems are typically non-intelligent.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES

Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.4 Entity Operation. The entities need not respond to the simulated air vehicle.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.4 Entity Operation. The following definitions apply to operation of the entities required by paragraph 3.7.1.5.6:

a. Intelligent - The entity automatically responds to all information that can be determined through its sensor(s). The response follows the doctrine, tactics, and procedures of the nation who operates the system represented by the entity as well as available design criteria. The response of the system is based on the overall situation to the extent required by this specification. For entities representing manned systems, the response is based on the mental and physical capacity of typical system operators.

b. Algorithmic - The entity automatically responds to all information that can be determined through its sensor(s). The response is typical of the tactics and procedures of the nation who operates the system represented by the entity as well as available design criteria. The response of the system is based on the overall situation to the extent required by this specification.

c. Simplified - The entity responds to the simulated air vehicle based on its current position, velocity, and electronic emissions. The response of the system is based on the overall situation to the extent required by this specification.

d. Non-intelligent - The entity does not respond to the simulated air vehicle or the overall situation.

In addition, entities shall be commanded in accordance with paragraph 3.7.4. If such commands conflict with other required operation, the commands shall override.

3.7.1.5.4.1 Operation Level. The following definitions apply to the level associated with operation of the entities required by paragraph 3.7.1.5.6: (1)

a. Perfect - The entity represents a real system operated perfectly by a fully trained operator who is unaffected by any environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.) or the entity represents an unmanned system operating in accordance with design criteria.

b. High - The entity represents a real system operated by a fully trained, highly-capable operator who is minimally affected by any environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.).

c. Moderate - The entity represents a real system operated by a capable operator or a fully-trained, highly-capable operator whose effectiveness is reduced by environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.).

d. Reduced - The entity represents a real world system operated by an operator who is inexperienced, poorly-trained, or severely affected by environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.), or the entity represents an unmanned system operating in a degraded mode.

e. Commanded - The entity is operated by command.

4.2.1.7.1.5.4.1 Verification of Operation Level. Verification of this requirement is not applicable.

RATIONALE

This requirement applies only to intelligent entities. The intent of this paragraph is to describe the operational response level built into a given entity. The requirement for modeling of operation levels is subjective and difficult to describe. The specification defines four grades of skill levels, in addition to a "commanded" level. The most difficult to assess for correct implementation are those which would correspond best to specific real-world situations -- i.e., the "high", "moderate", and "reduced" operational levels. However, some judgment will also be required for assessing the implementation of the "perfect" level. Past simulations have typically included only the "perfect" and "commanded" levels.

Requirements Guidance:

1. *Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.*

EXAMPLES

Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.4.1 Operation Level. The following definitions apply to the level associated with operation of the entities required by paragraph 3.7.1.5.6:

a. Perfect - The entity represents a real system operated perfectly by a fully trained operator who is unaffected by any environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.) or the entity represents an unmanned system operating in accordance with design criteria.

b. Commanded - The entity is operated by command.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.4.1 Operation Level. The following definitions apply to the level associated with operation of the entities required by paragraph 3.7.1.5.6:

a. Perfect - The entity represents a real system operated perfectly by a fully trained operator who is unaffected by any environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.) or the entity represents an unmanned system operating in accordance with design criteria.

b. High - The entity represents a real system operated by a fully trained, highly-capable operator who is minimally affected by any environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.).

c. Moderate - The entity represents a real system operated by a capable operator or a fully-trained, highly-capable operator whose effectiveness is reduced by environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.).

d. Reduced - The entity represents a real world system operated by an operator who is inexperienced, poorly-trained, or severely affected by environmental factors (e.g., weather, ambient noise, lack of food, lack of sleep, etc.), or the entity represents an unmanned system operating in a degraded mode.

e. Commanded - The entity is operated by command.

3.7.1.5.5 Aggregate Entities. (1)When required by paragraph 3.7.1.5.6, entities shall be aggregate entities. An aggregate entity contains other entities, and separates into separate entities upon command. The separation activity is named deaggregation. Certain entities join to form aggregate entities upon command. This activity is named aggregation.

4.2.1.7.1.5.5 Verification of Aggregate Entities. Verification of this requirement is not applicable.

RATIONALE
An entity may contain other entities. For example, an aircraft carrier could contain aircraft which would in turn contain missiles or bombs. A tank could contain a missile or gun rounds. A cargo aircraft could contain paratroopers. Aggregation is an activity where two entities combine to form a single aggregate entity, such as an aircraft returning to an aircraft carrier or a cargo aircraft loading cargo. Deaggregation is an activity where the aggregate entity spawns other entities, such as an aircraft carrier launching aircraft, an aircraft firing a missile, or a cargo aircraft dropping paratroopers.

Requirements Guidance:

1. *Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.*

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.5 Aggregate Entities. This requirement is not applicable.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.5 Aggregate Entities. When required by paragraph 3.7.1.5.6, entities shall be aggregate entities. An aggregate entity contains other entities, and separates into separate entities upon command. The separation activity is named deaggregation. Certain entities join to form aggregate entities upon command. This activity is named aggregation.

3.7.1.5.5.1 Aggregate Entity Logistics Fidelity. Aggregate Entity Logistics Fidelity. Each aggregate entity in paragraph 3.7.1.5.6 shall deaggregate entities upon command with the logistics fidelity described in the subparagraphs below: (1)

a. Replicated - All logistics aspects associated with the system represented by the entity shall be fully modeled. This includes:

1) Capacity of the system to carry or use other vehicles or weapons.

2) Mix of vehicles carried or used by the system.

3) Time to reload and return to combat operations.

4) Maximum rates of fire and vehicle launch.

Replicated logistics fidelity applies to a specific system, i.e., type of aircraft (e.g., Flogger A), unique ship (e.g., USS John F. Kennedy), type of vehicle (e.g., M1A1 tank), type of weapon (e.g., AIM 120) or type of unit (e.g., Soviet Army platoon).

b. Generically replicated - Provides logistics fidelity typical of the system being simulated as defined by design criteria. Subparagraphs of **a** apply . Generically replicated refers to typical systems (e.g., aircraft Soviet fighter), class of ship (e.g., US aircraft carrier), class of vehicle (e.g., US tank), class of weapon (e.g., air-to-air missile), or class of unit (e.g., infantry). Actual intelligence data for a representative system may be used.

c. Partially replicated - Some of the subparagraphs listed in **a** are not required.

d. Unlimited - Logistics aspects are not simulated. The entity has infinite capacity to launch vehicles or weapons.

e. Not required - The entity does not deaggregate into other entities.

4.2.1.7.1.5.5.1 Verification of Aggregate Entity Logistics Fidelity. Verification of this requirement is not applicable.

RATIONALE
Fidelity is very subjective and difficult to describe. The specification defines grades of fidelity. Clearly the higher the fidelity grade the closer the match to the real world. Some judgment will be required in evaluating fidelity in all cases.

a. "Replicated" tries to match the real world to the extent it can be defined by design criteria.

b. "Generically replicated" tries to provide systems typical of the real world, but which may not exactly match any one real world system.

c. "Partially replicated" means that fidelity is deliberately reduced. The degree of reduction must be described in paragraph 3.7.1.5.6.

d. "Unlimited" implies that logistics aspects are not simulated, and that firing capacity is infinite.

e. "Not required" means that the entity does not deaggregate.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5. The paragraph should be deleted.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.5.1 Aggregate Entity Logistics Fidelity. Each aggregate entity in paragraph 3.7.1.5.6 shall deaggregate entities upon command with the logistics fidelity described in the subparagraphs below:

a. Replicated - All logistics aspects associated with the system represented by the entity shall be fully modeled. This includes:

1) Capacity of the system to carry or use other vehicles or weapons.

2) Mix of vehicles carried or used by the system.

3) Time to reload and return to combat operations.

4) Maximum rates of fire and vehicle launch.

Replicated logistics fidelity applies to a specific system, i.e., type of aircraft (e.g., Flogger A).

b. Generically replicated - Provides logistics fidelity typical of the system being simulated as defined by design criteria. Subparagraphs of a apply . Generically replicated refers to typical systems (e.g., aircraft Soviet fighter), class of weapon (e.g., air-to-air missile), or class of unit (e.g., infantry). Actual intelligence data for a representative system may be used.

c. Partially replicated - Some of the subparagraphs listed in **a** are not required.

d. Unlimited - Logistics aspects are not simulated. The entity has infinite capacity to launch vehicles or weapons.

3.7.1.5.5.2 Weapons Fidelity. For those entities specified in paragraph 3.7.1.5.6 which represent weapons, the following definitions shall apply to the minimum level of fidelity required for representing explosive characteristics. These definitions shall also apply to weapons launched by the simulated air vehicle. (1)

a. Replicated - the weapon's explosive characteristics shall exactly match design criteria with respect to fusing time or range, explosive force, and directivity of that force. Environmental conditions shall effect the fusing and explosion of the weapons.

b. Approximated - the weapon's explosive characteristics performance is approximated.

c. Not required - no modeling of explosive characteristics is required.

4.2.1.7.1.5.5.2 Verification of Weapons Fidelity. Verification of this requirement is not applicable.

RATIONALE
Weapons (those launched by the simulated air vehicle as well as other entities) are entities in themselves. The requirements for entities also apply to weapon entities; in addition, weapons typically have a warhead that must be represented. Where approximated fidelity is required, the degree of approximation must be described in paragraph 3.7.1.5.6.

Requirements Guidance:

1. Tailor the definitions to delete or modify any part that is not applicable to a particular simulator.

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5. The paragraph should be deleted.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.5.2 Weapons Fidelity. For those entities specified in paragraph 3.7.1.5.6 which represent weapons, the following definitions shall apply to the minimum level of fidelity required for representing

explosive characteristics. These definitions shall also apply to weapons launched by the simulated air vehicle.

a. Replicated - the weapon's explosive characteristics shall exactly match design criteria with respect to fusing time or range, explosive force, and directivity of that force. Environmental conditions shall effect the fusing and explosion of the weapons.

b. Approximated - the weapon's explosive characteristics performance is approximated.

c. Not required - no modeling of explosive characteristics is required.

3.7.1.5.6 Entity Identification. The following systems shall be represented by entities:

___1___.

4.2.1.7.1.5.6 Verification of Entity Identification. This requirement shall be verified by test. Each unique entity shall be tested to verify all requirements.

RATIONALE

The purpose of this paragraph is to identify all entities to be simulated, and the requirements for fidelity for each simulated entity in accordance with the definitions of paragraph 3.7.1.5 and its subparagraphs. Each entity identified should be tested against all requirements.

Requirements Guidance:

1. *The steps in filling in this blank are:*

   a. *Identification of each entity to be represented (see 3.7.1.5).*

   b. *Identification of the entity platform requirements for each entity. These include the entity platform signature (3.7.1.5.1.1 and 3.7.1.5.1.2) and the entity platform dynamics (3.7.1.5.1.3 and 3.7.1.5.1.4).*

   c. *Identification of the entity emitter requirements for each entity. These include the emissions (3.7.1.5.2.1) and the emitter fidelity (3.7.1.5.2.2). Note that an entity may have more than one emitter.*

   d. *Identification of the entity sensor requirements for each entity. These include the sensor fidelity (3.7.1.5.3.1) and interconnectivity (3.7.1.5.3.2). Note that an entity may have more than one sensor.*

   e. *Identification of each entity's operation (3.7.1.5.4) and operation level (3.7.1.5.4.1).*

   f. *Determine whether each entity is an aggregate entity or not. Also determine whether each entity can aggregate with other entities. Assure that all entities which aggregate or deaggregate from other entities are listed. Assure own ship weapons are listed as entities. For aggregate entities, determine the logistic fidelity (3.7.1.5.5.1). For weapons, determine the weapons fidelity (3.7.1.5.5.2).*

In performing steps a through f, be sure to define degrees of partial replication, approximation, etc., when necessary.

This is a long complex process. In many cases it can be simplified by tailoring requirements as previously discussed. Use of a table may be advisable.

Process Guidance: *This paragraph will need considerable refinement as the program progresses in order to capture all details of entity representation. Early in a program the requirement can be stated generically, and more details added as the program progresses.*

EXAMPLES
Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.6 Entity Identification. The following systems shall be represented by entities:

a. Global Position System Satellites and Ground Stations. The emitter fidelity associated with these entities shall be approximated. The entity emissions shall be approximated to provide sufficient information to the simulated air vehicle to allow accurate position computations. Entity operation level shall be perfect. Sufficient systems shall be represented to provide coverage over the entire gaming area.

b. All radio navigation stations associated with all airways in the gaming area shall be represented. The entity emissions shall be approximated such that the simulated aircraft can detect when it is in range of the station, as well as range and bearing to the station. Frequency shall match design criteria. Entity operation level shall be perfect.

c. All TACAN stations in the gaming area shall be represented. The entity emissions shall be approximated such that the simulated aircraft can detect when it is in range of the station, as well as range and bearing to the station. Frequency shall match design criteria. Entity operation level shall be perfect.

d. Air Traffic Control Centers at Chicago IL and Indianapolis IN shall be represented. The entity emissions shall be approximated. Frequency shall match design criteria. Detection range shall be a constant 150 miles. Entity operation level shall be commanded.

e. All ILS systems at Chicago IL, Indianapolis IN, and Des Moines IA shall be represented. Entity emissions shall be replicated. Entity operation level shall be perfect.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.6 Entity Identification. The following systems shall be represented by entities:

a. F-16A, F-16C, F-15A, and F-15C. Requirements for entities representing these systems shall be as follows:

Entity Platform Signatures: Mutable.
Entity Platform Signature Fidelity: Replicated.
Entity Platform Dynamics Control: Mobile.
Entity Platform Dynamics Fidelity: Replicated.
Emitters: Fire Control radars and IFF systems associated with each entity as defined by design criteria.
Emissions: Immutable.
Emitter Fidelity: Replicated.
Sensor Fidelity: Null.
Interconnectivity: Not interconnected.
Entity Operation: Algorithmic.
Operation Level: Perfect and Commanded.
Aggregate Entities: AIM-7F, AIM-9L, chaff, flares, gun rounds, and AIM 120.
Aggregate Entity Logistics Fidelity: Unlimited.

b. Aim-7F, AIM-9L, and AIM-120. Requirements for entities representing these weapons shall be as follows:

Entity Platform Signatures: Immutable.

Entity Platform Signature Fidelity: Approximated. The weapons shall be represented by objects with similar size, shape, and color.
Entity Platform Dynamics Control: Mobile.
Entity Platform Dynamics Fidelity: Replicated.
Entity Operation: Intelligent.
Operation Level: Perfect.
Weapons Fidelity: Replicated when representing weapons launched by the simulated air vehicle or by entities in combat with the simulated air vehicle. Null in all other cases.

c. Chaff and Flares. Requirements for entities representing these expendables shall be as follows:

Entity Platform Signatures: Immutable.
Entity Platform Signature Fidelity: Approximated. Chaff shall grow linearly to a 5 meter square target within 10 seconds of launch; the cloud shall dissipate within 3 minutes. Flares shall represent a larger heat source than the launching entity; they shall extinguish 5 seconds after launch.
Entity Platform Dynamics Control: Mobile.
Entity Platform Dynamics Fidelity: Approximated. Chaff shall fall to the earth at a rate of 1 foot per second. Chaff shall move with any simulated wind. Flares shall fall to earth at a rate of 20 feet per second.
Entity Operation: Non-intelligent.
Operation Level: Perfect.

d. SU-27 and SU-29. Requirements for entities representing these systems shall be as follows:

Entity Platform Signatures: Mutable.
Entity Platform Signature Fidelity: Replicated.
Entity Platform Dynamics Control: Mobile.
Entity Platform Dynamics Fidelity: Replicated.
Emitters: Fire control radars, IFF, and systems associated with each aircraft as defined by design criteria.
Emissions: Mutable.
Emitter Fidelity: Replicated.
Sensor Fidelity: Replicated.
Interconnectivity: Interconnected.
Entity Operation: Intelligent.
Operation Level: High, moderate, reduced, commanded.
Aggregate Entities: AA-10, AA-11, AA-12, AA-13, chaff, flare, and gun rounds.
Aggregate Entity Logistics Fidelity: Replicated.

e. AA-10, AA-11, AA-12, and AA-13. Requirements for entities representing these systems shall be as follows:

Entity Platform Signatures: Immutable.
Entity Platform Signature Fidelity: Approximated. The weapons shall be represented by objects with similar size, shape, and color.
Entity Platform Dynamics Control: Mobile.
Entity Platform Dynamics Fidelity: Replicated.
Entity Operation: Intelligent.
Operation Level: Perfect.
Weapons Fidelity: Replicated.

g. Gun Rounds. Requirements for entities representing these weapons shall be as follows:

Entity Platform Signatures: Immutable.

Entity Platform Signature Fidelity: Approximated. Muzzle flashes shall be visible when the simulated aircraft is within five nautical miles of the simulated guns.
Entity Platform Dynamics Control: Mobile.
Entity Platform Dynamics Fidelity: Approximated. The trajectory shall be approximated based on the PQR Gun and its pointing angle. All shells in a burst shall follow the same trajectory.
Entity Operation: Non-intelligent.
Operation Level: Perfect.
Entity Operation: Non intelligent.
Operation Level: Perfect.
Weapons Fidelity: Approximated. All shells shall be assumed to be 50 mm high explosive. The 50 mm high explosive shell shall be replicated for the first shell in a burst. Each additional round fired shall increase the calculated damage by a fixed increment.

h. Sa-1, Sa-2, Sa-3, Sa-4, Sa-5, Sa-6, Sa-7, Sa-8, Sa-9, Sa-10, Sa-11, and Sa-12. Requirements for entities representing these systems shall be as follows:

Entity Platform Signatures: Null.
Entity Platform Dynamics Control: Immobile.
Emitters: Search and track radars associated with each system as defined by design criteria.
Emissions: Replicated.
Emitter Fidelity: Replicated.
Sensor Fidelity: Replicated.
Interconnectivity: Interconnected and non-interconnected as specified in the simulator mission script.
Entity Operation: Algorithmic.
Operation Level: Perfect.
Aggregate Entities: Missiles associated with each system as defined by design criteria.
Aggregate Entity Logistics Fidelity: Unlimited.

h. Sa-1, Sa-2, Sa-3, Sa-4, Sa-5, Sa-6, Sa-7, Sa-8, Sa-9, Sa-10, Sa-11, and Sa-12 missiles. Requirements for entities representing these missiles shall be as follows:

Entity Platform Signatures: Immutable.
Entity Platform Signature Fidelity: Approximated. The weapons shall be represented by objects with similar size, shape, and color.
Entity Platform Dynamics Control: Mobile.
Entity Platform Dynamics Fidelity: Approximated. A lead collision guidance algorithm shall approximate the flight path.
Entity Operation: Non-intelligent.
Operation Level: Perfect.
Weapons Fidelity: The Sa-4 missile warhead shall be replicated. All other missile warheads shall be approximated in that they will be approximated by the SA-4 warhead.

h. Hostile Air Defense Control Centers. Requirements for entities representing these systems shall be as follows:

Entity Platform Signatures: Null.
Entity Platform Dynamics Control: Immobile.
Interconnectivity: Interconnected and non-interconnected as specified in the simulator mission script.
Entity Operation: Algorithmic.
Operation Level: Perfect.

All the above entities having interconnectivity listed as "interconnected" shall be connected to Air Defense Control Centers as specified in the simulator mission script. Entities representing Air Defense Control Centers shall be connected to other entities representing Air Defense Control Centers as specified in the simulator mission script.

Example 3. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5. Example 2 also covers this case; however, the detail shown in example 2 will often not be defined until well into a program. At the initial System Specification level, this requirement might be written as follows.

3.7.1.5.6 Entity Identification The following systems shall be represented by entities:

a. F-15, F-16, SU-27, and SU-29 aircraft shall be represented by mobile entity platforms. Entity platform dynamics fidelity and emitter fidelities shall be replicated. The F-16 entities shall represent other aircraft in the same flight as the simulated air vehicle. The F-15 entities shall represent a combat air patrol operating in the same area as the simulated air vehicle. The Su-27 and SU-29 entities shall represent systems which engage in simulated air-to-air combat with the simulated air vehicle (within and beyond visual range) upon command. The SU-27 and SU-29 entities shall be interconnected with entities representing Air Defense Control Centers to represent hostile air defense networks as determined by simulator mission scripts.

b. Twelve hostile air defense missile systems shall be represented by entities. Emitter fidelities of these entities shall be replicated. These entities shall be interconnected with entities representing Air Defense Control Centers as determined by simulator mission scripts.

Other entity requirements shall be sufficient to:

a. Provide all cues and reactions associated with simulated air combat against skilled opponents in the SU-27 and SU-29 entities.

b. Provide indications of missile launches and gun fire in combat. Weapon fidelity may be approximated.

c. Represent typical air defense systems encountered by the simulated air vehicle.

Note that when a specification statement such as Example 3 is used, tasks should be included in the Statement of Work that will continue to define the requirement until the level of detail illustrated in Example 2 is reached.

3.7.1.5.7 Entity Instantiation. All entity instantiation requirements shall apply simultaneously. At any instant in a simulator exercise up to __1__ entities with __2__ entity emitters shall be interacting with the simulated air vehicle or other entities. (3)Up to __4__ entities with __5__ emitters shall interact with the simulated air vehicle or other entities during an entire simulation exercise. The entities interacting at any instant in a simulator exercise shall consist of up to:

CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVE APPROACHES TO COMPLETE THE REQUIREMENT:

FIRST ALTERNATIVE:

a. __6__ entities representing individual fighter, bomber, and attack aircraft.

b. __6__ entities representing individual elements of air defense networks.

c. __6__ entities representing individual elements of ground forces.

d. __6__ entities representing individual elements of naval forces.

e. __6__ entities representing air refueling aircraft.

f. __6__ entities representing AWACS, JSTARS, and similar standoff support aircraft.

g. __6__ entities representing EF-111A, EA-6B, and similar jammer aircraft.

h. __6__ entities representing C4I aircraft and stations.

i. __6__ entities representing the Global Positioning System.

j. __6__ entities representing airways.

k. __6__ entities representing LORAN stations.

l. __6__ entities representing OMEGA stations.

m. __6__ entities representing TACAN Stations.

n. __6__ entities representing Air Traffic Control Centers.

o. __6__ entities representing ILS at airfields.

__7__.

(8)The entities interacting in a total simulator exercise shall include:

a. __9__ entities representing individual fighter, bomber, and attack aircraft.

b. __9__ entities representing individual elements of air defense networks.

c. __9__ entities representing individual elements of ground forces.

d. __9__ entities representing individual elements of naval forces.

e. __9__ entities representing air refueling aircraft.

f. __9__ entities representing AWACS, JSTARS, and similar standoff support aircraft.

g. __9__ entities representing EF-111A, EA-9B, and similar jammer aircraft.

h. __9__ entities representing C4I aircraft and stations.

i. __9__ entities representing the Global Positioning System.

j. __9__ entities representing airways.

k. __9__ entities representing LORAN stations.

l. __9__ entities representing OMEGA stations.

m. __9__ entities representing TACAN Stations.

n. __9__ entities representing Air Traffic Control Centers.

o. __9__ entities representing ILS at airfields.

__10__.

__11__.

-OR- SECOND ALTERNATIVE:

a. __12__ entities with mutable entity platform signatures.

b. __13__ entities with mutable entity platform signatures with replicated signature fidelity.

c. __13__ entities with mutable entity platform signatures with generically replicated signature fidelity.

d. __13__ entities with mutable entity platform signatures with partially replicated signature fidelity.

e. __12__ entities with immutable entity platform signatures.

f. __13__ entities with immutable entity platform signatures with replicated signature fidelity.

g. __13__ entities with immutable entity platform signatures with generically replicated signature fidelity.

h. __13__ entities with immutable entity platform signatures with partially replicated signature fidelity.

i. __12__ entities with mobile entity platforms.

j. __13__ entities with mobile entity platforms and replicated entity platform dynamics fidelity.

k. __13__ entities with mobile entity platforms and partially replicated entity platform dynamics fidelity.

l. __12__ entities with entity sensors.

m. __12__ entities with entity sensors with replicated sensor fidelity.

n. __12__ entities with entity sensors with partially replicated sensor fidelity.

o. __12__ entities that are fully networked.

p. __12__ entities that are interconnected.

q. __12__ entities with limited interconnectivity.

r. __12__ entities with intelligent entity operation.

s. __12__ entities with algorithmic entity operation.

t. __12__ entities with simplified entity operation.

u. __12__ entities with perfect operation level.

v. __12__ entities with a high operation level.

w. __12__ entities with moderate operation level.

x. __12__ entities with reduced operation level.

y. __12__ entities with commanded operation level.

z. __12__ aggregate entities.

aa. __12__ aggregate entities with replicated logistics fidelity.

ab. __12__ aggregate entities with generically replicated logistics fidelity.

ac. __12__ aggregate entities with partially replicated logistics fidelity.

ad. __12__ aggregate entities with unlimited logistics fidelity.

ae. __12__ entities representing weapons with replicated weapons fidelity.

af. __12__ entities representing weapons with approximated fidelity.

__14__.

__15__.

Up to __12__ entities with entity emitters shall be represented at any instant in the simulator exercise.

a. __16__ emitters with mutable emissions.

b. __17__ emitters with mutable emissions with replicated emitter fidelity.

c. __17__ emitters with mutable emissions with generically replicated emitter fidelity.

d. __16__ emitters with immutable emissions.

e. __17__ emitters with immutable emissions with replicated emitter fidelity.

f. __17__ emitters with immutable emissions with generically replicated emitter fidelity.

__18__.

(19)The entities interacting in a total simulator exercise shall include:

a. __20__ entities with mutable entity platform signatures.

b. __21__ entities with mutable entity platform signatures with replicated signature fidelity.

c. __21__ entities with mutable entity platform signatures with generically replicated signature fidelity.

d. __21__ entities with mutable entity platform signatures with partially replicated signature fidelity.

e. __20__ entities with immutable entity platform signatures.

f. __21__ entities with immutable entity platform signatures with replicated signature fidelity.

g. __21__ entities with immutable entity platform signatures with generically replicated signature fidelity.

h. __21__ entities with immutable entity platform signatures with partially replicated signature fidelity.

i. __20__ entities with mobile entity platforms.

j. __21__ entities with mobile entity platforms and replicated entity platform dynamics fidelity.

k. __21__ entities with mobile entity platforms and partially replicated entity platform dynamics fidelity.

l. __20__ entities with entity sensors.

m. __20__ entities with entity sensors with replicated sensor fidelity.

n. __20__ entities with entity sensors with partially replicated sensor fidelity.

o. __20__ entities that are fully networked.

p. __20__ entities that are interconnected.

q. __20__ entities with limited interconnectivity.

r. __20__ entities with intelligent entity operation.

s. __20__ entities with algorithmic entity operation.

t. __20__ entities with simplified entity operation.

u. __20__ entities with perfect operation level.

v. __20__ entities with a high operation level.

w. __20__ entities with moderate operation level.

x. __20__ entities with reduced operation level.

y. __20__ entities with commanded operation level.

z. __20__ aggregate entities.

aa. __20__ aggregate entities with replicated logistics fidelity.

ab. __20__ aggregate entities with generically replicated logistics fidelity.

ac. __20__ aggregate entities with partially replicated logistics fidelity.

ad. __20__ aggregate entities with unlimited logistics fidelity.

ae. __20__ entities representing weapons with replicated weapons fidelity.

af. __20__ entities representing weapons with approximated fidelity.

__22__.

__23__.

Up to __20__ entities with entity emitters shall be represented at any instant in the simulator exercise.

a. __24__ emitters with mutable emissions.

b. __25__ emitters with mutable emissions with replicated emitter fidelity.

c. __25__ emitters with mutable emissions with generically replicated emitter fidelity.

d. __24__ emitters with immutable emissions.

e. __25__ emitters with immutable emissions with replicated emitter fidelity.

f. __25__ emitters with immutable emissions with generically replicated emitter fidelity.

__26__.

__27__.

4.2.1.7.1.5.7 Verification of Entity Instantiation. This requirement shall be verified by analysis and test. Simulator exercises shall verify all requirements, and analysis of these exercises shall assure that each required limit is achieved.

RATIONALE
Entity instantiation deals with two issues. The first -- and most important -- is the instantaneous instantiation. This is the number of entities that can be involved in a simulation exercise at any given instant of a simulator exercise. The processing power must be sized to be capable of simultaneously simulating these entities (i.e., moving them, generating sensor displays, displaying them visually, performing logic associated with their operation, etc.). For example, entities with mobile platforms and mutable platform signatures can present a significant processing load to an image generator due to the additional matrix math required to handle the separate coordinate systems (some image generator architectures are more forgiving of this additional load than others; sometimes displayed feature density may have to be reduced when mobile entities are brought into the scene). A mix including 20 entities with mobile platforms has been used as a good rule of thumb in the past. The specific mix is highly dependent on particular applications and contractor approaches.

The second -- and usually less important -- issue is the entity capacity of a particular exercise. This requirement affects data storage, and could affect the complexity of the priority scheme for selecting the instantaneous entities from all those available for the exercise. If a specific limit is not stated, the higher order limit applies by default (e.g., if no mobile entity platform limit is stated, then all entities can be mobile).

Requirements Guidance:

1. Fill in the total number of entities interacting at any instant in a simulator exercise.

2. Fill in the total number of entity emitters associated with the entities entered in blank (1); if none are required delete "with __2__ entity emitters".

3. Delete the entire sentence following (3) if the total entities in an exercise are not limited.

4. Fill in the total number of entities interacting in an entire simulator exercise.

5. Fill in the total number of entity emitters associated with the entities entered in blank (2); if none are required, or if the number is not significant, delete "with __5__ entity emitters".

6. Fill in the total number of required entities of each type. If a type is not required, or if the number of entities of that type is not limited, the item may be deleted. This number cannot exceed what was entered in blank (1) -- i.e., the total number of entities interacting at a given instant in the simulator exercise.

7. Add any other limitation on entities interacting at any instant. For example, "Only a single entity representing the MIG-29 shall be instantiated."

8. Delete the remainder of the requirement following (8) if the total entities in an exercise are not limited.

9. Fill in the total number of required entities of each type. If a type is not required, or if the number of entities of that type is not limited, the item may be deleted. This number cannot exceed what was entered in blank (5) -- i.e., the total number of entities interacting during the simulator exercise.

10. Add any other limitation on entities interacting in an exercise. For example, "Only a single entity representing an aircraft carrier shall be instantiated."

11. Add a description of how the total entities in an exercise are reduced to the instantaneous entities. This is usually some arbitrary, non-real-world priority scheme. Real-world sensors can be overloaded, but some additional processing is required for each entity.

12. Fill in the total number of required entities of each type. If a type is not required or the number of entities of that type is not limited the item may be deleted. This number cannot exceed what was entered in blank (1) -- i.e., the total number of entities interacting at a given instant in the simulator exercise.

13. Fill in the total number of required entities of each type. If a type is not required or the number of entities of that type is not limited the item may be deleted. This number must not exceed the total number of entities interacting at a given instant required by the immediately preceeding blank (12) entry.

14. Add any other limitation on entities interacting at any instant. For example, "Only a single entity representing the MIG-29 shall be instantiated."

15. Discuss any limitations on interconnected entities. For example, "Up to three groups of interconnected entities shall be instantiated. Each group shall consist of up to 25 entities."

16. Fill in the total number of emitters of each type. If a type is not required, or the number of emitters of that type is not limited, the item may be deleted. This number cannot exceed what was entered in blank (2) -- i.e., the total number of emitters interacting at a given instant in an exercise.

17. Fill in the total number of emitters of each type. If a type is not required or the number of emitters of that type is not limited, the item may be deleted. This number must not exceed the total number of emitters interacting at a given instant required by the immediately preceeding blank (16) entry.

18. Add any other limitation on emitter interacting at any instant. For example, "No more than seven entity emitters shall represent radars with conical scans. Any emitter shall represent a radar with up to seven beams (unique signal characteristics); however the average number of beams associated with each entity emitter representing a radar need not exceed three."

19. Delete the remainder of the requirement if the total entities in an exercise are not limited.

20. Fill in the total number of required entities of each type. If a type is not required or the number of entities of that type is not limited, the item may be deleted. This number cannot exceed what was entered in blank (4) -- i.e., the total number of entities interacting in the simulator exercise.

21. Fill in the total number of required entities of each type. If a type is not required or the number of entities of that type is not limited, the item may be deleted. This number must not exceed the total number of interacting entities required by the immediately preceeding blank (20) entry.

22. Add any other limitation on entities interacting in a simulator exercise. For example, "Only a single entity representing an aircraft carrier shall be instantiated."

23. Discuss any limitations on interconnected entities. For example, "Up to three groups of interconnected entities shall be instantiated. Each group shall consist of up to 25 entities."

24. Fill in the total number of emitters of each type. If a type is not required or the number of emitters of that type is not limited the item may be deleted. This number cannot exceed what was entered in blank (5) -- i.e., the total number of emitters interacting in an exercise.

25. Fill in the total number of emitters of each type. If a type is not required or the number of emitters of that type is not limited, the item may be deleted. This number must not exceed the total number of emitters interacting at a given instant in an exercise required by the immediately preceeding blank (24) entry.

26. Add any other limitation on emitter interactions in an exercise. For example, "No more than seven entity emitters shall represent radars with conical scans. Any emitter shall represent a radar with up to seven beams (unique signal characteristics); however the average number of beams associated with each entity emitter representing a radar need not exceed three."

27. Add a description regarding how the instantaneous entities are to be selected from the total set of entities available in an exercise. This is usually some arbitrary, non real-world priority scheme.

Process Guidance:

This is a very complex paragraph. It will usually be necessary to state the requirement simply at early program stages and refine it as the program progresses. The Statement of Work should require review and update at PDR and CDR.

EXAMPLES

Example 1. A primary training aircraft with no combat simulation. This continues the example started in 3.7.1.5.

3.7.1.5.7 Entity Instantiation. All entity instantiation requirements shall apply simultaneously. At any instant in a simulator exercise up to 46 entities shall be interacting with the simulated air vehicle or other entities. Up to 100 entities shall interact with the simulated air vehicle or other entities during an entire simulation exercise. The entities interacting at any instant in a simulator exercise shall consist of up to:

a. 15 entities representing the Global Positioning System.

b. 25 entities representing airways.

c. 3 entities representing TACAN Stations.

d. 2 entities representing Air Traffic Control Centers.

e. An entity representing ILS at airfields.

The entities interacting in a total simulator exercise shall include:

a. 15 entities representing the Global Positioning System.

b. 100 entities representing airways.

c. 50 entities representing TACAN Stations.

d. 2 entities representing Air Traffic Control Centers.

e. 3 entities representing ILS at airfields.

Those entities interacting with the simulated air vehicle at any instant of time shall be the entities of each of the above types closest to the simulated air vehicle position.

Example 2. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5.

3.7.1.5.7 Entity Instantiation. All entity instantiation requirements shall apply simultaneously. At any instant in a simulator exercise up to 70 entities with 100 entity emitters shall be interacting with the simulated air vehicle or other entities. The entities interacting at any instant in a simulator exercise shall consist of up to:

a. 5 entities with mutable entity platform signatures.

b. 10 entities with immutable entity platform signatures.

c. 15 entities with mobile entity platforms.

d. 5 entities with mobile entity platforms and replicated entity platform dynamics fidelity.

e. 50 entities with entity sensors.

f. 50 entities that are interconnected.

g. 5 entities with intelligent entity operation.

h. 45 entities with algorithmic entity operation.

i. 45 entities with perfect operation level.

j. 5 aggregate entities.

Only a single entity representing the SU-27 or SU-29 need be instantiated.

Up to 60 entities with entity emitters shall be represented at any instant in the simulator exercise.

Example 3. An air-to-air combat part task trainer. This continues the example started in 3.7.1.5. In this case, it is too early in the program to define all the limits above.

3.7.1.5.7 Entity Instantiation. All entity instantiation requirements shall apply simultaneously. At any instant in a simulator exercise up to 70 entities with 100 entity emitters shall be interacting with the simulated air vehicle or other entities. Other limits on specific entity and emitter types shall be determined in accordance with the Statement of Work.

3.7.2 Cue Generators.

4.2.1.7.2 Verification of Cue Generators. Verification of this requirement is not applicable.

RATIONALE

This is a title-only paragraph. Cue generators provide the interface between the synthetic environment and the simulated air vehicle. They do not have any real-world correlate, but rather consist of simulator-

unique systems that allow the aircrew to observe the synthetic environment and its effects on the simulated air vehicle.

3.7.2.1 Visual System. The visual system shall process the environment data and display perspectively-correct imagery in accordance with the requirements of this specification. (1)Daylight, dusk, and night out-the-window (OTW) imagery shall be provided. (2)Daylight OTW imagery shall be in full color with scene content comparable in detail to that produced by 4000 edges or __2a__ polygons. (3)Dusk OTW imagery shall be in color with scene content sufficient to enable identification of a visible horizon and typical terrain characteristics such as fields, roads, and bodies of water. (4)OTW visual scene content shall be sufficient to recognize significant fixtures and to successfully assess sink rate and depth perception during low-level operations. The visual scene shall accurately portray the synthetic environment in relationship to the simulated aircraft's attitude and position. Temporal and spatial aliasing shall be reduced to non-distracting levels without introducing distracting color variations. (5)Load and environment data processing shall be managed to assure that manifestations of distracting overload conditions such as breakup, dropout, streaking, flashing, or discontinuities in any part of the visual scene are separated in time by at least __5a__ minutes, and that the duration of any such overload condition does not exceed __5b__ consecutive display frames. (6)In those situations where visual system load management necessitates that the number of entity platforms portrayed be less than the total number instantiated, the most critical subset of the instantiated entity platforms shall be portrayed. (7)__7a__ imagery shall be blanked during __7b__ activities. All requirements of this specification shall be met without readjustment of controls affecting image quality.

4.2.1.7.2.1 Verification of Visual System. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

This requirement shall be verified by demonstration (8)and analysis. All required visual system imagery shall be verified in conjunction with the following demonstrations of the "Airplane Flight Simulator Evaluation Handbook": (9)

Section 4b Visual system color
Section 4b Visual display focus and intensity
Section 4b Visual attitude correlation
Section 4d Visibility definition
Section 4e Airport scene content
Section 4g Flight compatibility

(10)Analysis during design reviews shall verify that visual system capacity is consistent with the requirement. (11)Analysis during design reviews and demonstration at maximum visibility over the full dynamic range of the simulated aircraft's translational and rotational rates shall verify that the visual system has adequate capacity for real-time retrieval and caching of environment data and the monitoring and controlling of overload conditions. (12)Analysis during design reviews and demonstration with the maximum number of instantaneously interacting entities instantiated shall verify that the visual system portrays the most critical entities. (13)Demonstration shall verify that the required imagery is blanked in accordance with the requirement.

-OR-

This requirement shall be verified by demonstration (8)and analysis. All required visual system imagery shall be verified in conjunction with the following demonstrations of Appendix 2 of AC-120-63 "Helicopter Simulator Qualification": (9)

Test 4b Visual system color
Test 4d Visual display focus and intensity
Test 4e Visual attitude vs. simulator attitude indicator (pitch and roll of horizon)

Visibility definition, airport scene content, and flight compatibility shall be demonstrated in accordance with AC-120-63 Appendix 3 Test 2. (10)Analysis during design reviews shall verify that visual system capacity is consistent with the requirement. (11)Analysis during design reviews and demonstration at maximum visibility over the full dynamic range of the simulated aircraft's translational and rotational rates shall verify that the visual system has adequate capacity for real-time retrieval and caching of environment data and the monitoring and controlling of overload conditions. (12)Analysis during design reviews and demonstration with the maximum number of instantaneously interacting entities instantiated shall verify that the visual system portrays the most critical entities. (13)Demonstration shall verify that the required imagery is blanked in accordance with the requirement.

RATIONALE

Top level visual system requirements are included in this paragraph. Detailed requirements are stated in the following subparagraphs. These requirements, as written, inherently assume the use of computer generated imagery and the display of all objects (at least those in any given display channel) in the same image plane. This is adequate for all commercial airplane and helicopter simulators and the vast majority of military simulators. However, a small percentage of military applications (e.g., part-task trainers to support training the precontact, contact, and fuel-transfer portions of air-refueling missions) may have very specialized requirements. For such cases the paragraphs in this section will need to be tailored accordingly, in performance-oriented terms. For example, there may be requirements for the visual system to provide cues that allow relative distances to be accurately judged over distances ranging from 8 to 50 feet. It may be important that the visual cues include stereopsis and/or parallax -- in addition to the occultation and relative size cues that are already provided for in the following section.

Commercial aviation regulatory agencies have a highly standardized set of visual system requirements for the various categories of simulators (see the "Examples" under "Other Government Documents" and "Non-Government Documents" in section 2.0 for references). These standards are largely understood by the vendors in the industry, and -- should questions arise -- it is expected that the vendors will work with the regulatory agency to assure that their product will result in a qualified simulator. Comments regarding regulatory standards are embedded in the guidance for this paragraph and its subparagraphs.

Requirements Guidance:

1. Tailor or delete the sentence following (1), depending upon this application's requirement for out-the-window (OTW) imagery. Level B airplane and helicopter simulators require night OTW imagery. Level C airplane and helicopter simulators require at least night and dusk imagery. Level D airplane and helicopter simulators require daylight imagery as well.

2. Delete or tailor the sentence following (2) if daylight OTW imagery was not included in sentence (1). By industry standards, the achievement of full color require that three phosphors be used (the strikingly limited range of colors attainable with a two-color system is obvious in a chromaticity diagram plot). Full color daylight imagery with scene content comparable in detail to that produced by 4000 edges or 1000 polygons is required for Level D airplane simulators; the same applies to Level D helicopter simulators, but with a 2000 polygon scene complexity instead. Put either "1000" or "2000" into blank (2a) according to the type of aircraft being simulated.

3. Delete or tailor the sentence following (3) if dusk OTW imagery was not included in sentence (1). Sentence (3) is a requirement for Level C and D airplane and helicopter simulators.

4. Delete or tailor the sentence following (4) if OTW imagery was not included in sentence (1). Sentence (4) is a requirement for Level B, C, and D airplane and helicopter simulators.

5. Environment data retrieval addresses whether the image generator's online storage capacity is sufficient to support displaying the complete real-time visual scene without overloading the data-retrieval process. Environment data caching refers to the maintenance of a sufficient portion of data regarding the environment surrounding the aircraft in active memory such that the image generator can have the

correct image ready as the aircraft makes abrupt changes in direction. Load management addresses the extent to which the image generator is designed to anticipate the amount of real-time data processing required in order to control data-processing overload conditions. There is no explicit requirement regarding environment data retrieval, caching, or load management processing for commercial aircraft simulators. However, military applications typically require more diversity in scene complexity than do commercial applications (which are limited to scenes around selected airfields).

In military simulators it is acceptable -- and often desirable -- to overload the image generator for short periods of time. If a system is designed such that overload conditions do not occur, the full capability of the image generator is not being exploited. If overload conditions are explicitly permitted, then constraints on overload manifestations must be included as well. If no explicit requirement regarding overload conditions is to be specified, delete the sentence following (5). Otherwise, specify the shortest duration that is acceptable between occurrences of overload conditions in blank (5a) (5 or more minutes are recommended), and put the maximum acceptable duration for an overload condition in blank (5b) (5 or fewer consecutive display frames are recommended).

6. Entity instantiation requirements (paragraph 3.7.1.5.7) define all required simultaneous entity interactions. The visual portrayal of mobile entity platforms (which translate to dynamic coordinate systems or DCS in the image generator) can present a significant processing load to the image generator. This issue is not explicitly addressed in commercial regulatory standards, but -- for Level C and D airplane and helicopter simulators -- the required number of interacting mobile entity platforms is modest (e.g., there is a requirement for ground and air hazards such as converging airborne traffic or trucks or another aircraft crossing the active runway). The potentially large number of entity platforms that can interact simultaneously in military simulations, however, can easily saturate image generation capacity if the displayed subset is not limited to some manageable number. Typically, a priority sorting algorithm is employed to determine the most critical subset of interacting mobile entity platforms for depiction by the image generator.

If the display of only the most critical subset of all instantiated interacting entities is acceptable for purposes of limiting image generator loading under more extreme scenarios, retain the sentence following (6). If limiting the number of instantiated interacting entities that are portrayed is unacceptable regardless of scenario, delete the sentence following (6).

7. It is advisable to blank OTW types imagery (including NVG imagery) when the simulated vehicle is undergoing unrealistic movements during real-time operations (e.g., during initialization and repositioning activities) in order to help prevent occurrences of simulator sickness.

If this feature is not required, delete the sentence following (7). Otherwise, identify the imagery that should be blanked during unrealistic movements in blank (7a). Normally this would include "OTW" and "NVG" imagery -- narrower field-of-view sensor imagery (such as EO) need not be blanked.

It is not desirable to blank this imagery during offline operations such as scenario development. Also, instructors infrequently make use of freeze events and unusual aircraft slue during normal training operations (e.g., to help a novice learn to lock-up a target, an instructor might freeze the aircraft's position, then have the student yaw the aircraft around to where a suitable target can be acquired). The specific conditions under which blanking is to be initiated should be defined in blank (7b); see the "Process Guidance" below in this regard.

***Verification Guidance:** Select the alternative consistent with the requirement. The first alternative is for airplane simulators, the second is for helicopter simulators. Note that the visibility definition, airport scene content, and flight compatibility procedures are written around ground operations at airports (i.e., specific simulation-significant fixtures). These procedures will have to be modified if they are not consistent with the requirements for this application (e.g., if ground operations are not required). If this is the case, use the referenced procedures as a guide, but rewrite them to be consistent with the simulator requirements.*

For the alternative selected:

8. If the sentences following (10), (11), and (12) are deleted in accordance with the guidance below, delete the phrase "and analysis" following (8).

9. The list of demonstrations following (9) includes demonstrations regarding visibility definition (the distances from which airport light points, runway markings, etc. are recognizable) and airport scene content (specific airport details, terrain characteristics, and landmarks at three specific airports). These are intended to verify the visual system's performance, not the adequacy of all proximity, navigation, mission, and simulation-significant fixture models; the latter should be assessed as a part of the verification of the environment modeling.

The "Airplane Flight Simulator Evaluation Handbook" test procedures included under visibility definition, airport scene content, and flight compatibility correspond to requirements in Appendix 2 (that also appear in Appendix 3) of the "International Standards for the Qualification of Airplane Flight Simulators". These requirements are not included in Appendix 2 of AC 120-63, but only in Appendix 3 of that document. For this reason, the latter three items are included only under the "Functions and Subjective Tests" for helicopters.

Tailor and add additional qualifications to the list of demonstrations following (9) as necessary to be consistent with the requirement (e.g., if the visibility distances or the 3 arc-minute resolutions specified in the evaluation handbook or AC-120-63 are inconsistent with the specific application, the applicable values must be stated).

10. Analysis of visual system capacity applies for Level D airplane and helicopter simulators only. This is intended to verify the required image generator capacity in accordance with the sentence following (2). If the sentence following (2) was deleted or tailored such that this analysis is not required, delete the sentence following (10).

11. This analysis and demonstration are intended to verify that the design of the visual system incorporates sufficient capacity for retrieving and caching environment data and for monitoring and controlling overload conditions. If there is no explicit requirement regarding data retrieval, caching, or load management processing (i.e., if the sentence following (5) was deleted), delete the sentence following (11).

When the requirement is retained, engineering analysis of the design documentation should verify that the system has adequate active database storage -- combined with sufficient online database storage (i.e., cache memory) -- to render all visual scene elements in real time without degraded image presentation due to overloaded data retrieval processing.

Analysis should also verify that the system has adequate capacity for monitoring and controlling the rendering of the visual scene in real time. The visual system must include provisions for handling those isolated instances where there is more data to process than the image generator can process at the requisite real-time update rate (i.e., there should be provisions for a controlled, graceful degradation of performance in these situations). Techniques typically employed to this end include: vertical interval stretch, field/frame repetition, pixel replication, and degraded update rate.

Demonstrations verifying this requirement should be conducted at a variety of altitudes and at the specified maximum visibility. The simulated aircraft should fly over the actual database at realistic airspeeds, attitude changes, and turn rates. Watch for sudden changes in level of detail, sudden appearance or disappearance of scene elements, and other distracting effects -- especially with sudden changes in attitude and direction.

12. This analysis and demonstration are intended to verify that the design of the visual system incorporates a reasonable means for selecting the most critical subset of interacting instantiated mobile

entity platforms for portrayal. If there is no explicit requirement (i.e., if the sentence following (6) was deleted), delete the sentence following (12).

When the requirement is retained, engineering analysis of the design documentation should verify that the system employs a priority filtering algorithm that identifies those entity platforms that are most critical from among those that are otherwise candidates for inclusion in the displayed imagery. Engineering analysis should also verify that the underlying rationale defining "most critical" is reasonable and acceptable.

An acceptable design solution will assure that a sufficient number of entity platforms are simultaneously portrayed such that the crewmembers' behavior does not vary from what it would be with all instantiated entity platforms simultaneously portrayed. Data regarding human channel capacity suggest that any one crewmember can simultaneously deal with no more than six to nine entity platforms. As a point of reference, past military applications have typically displayed no fewer than twenty of the most critical entities simultaneously.

Demonstrations verifying this requirement should be conducted using scenarios that maximize the number of interacting entity platforms simultaneously appearing in the field of view. Look for lower priority entity platforms that exhibit distracting behavior. As in other overload management situations, the filtering algorithm should result in graceful removal or addition of entities in the imagery; entities should not continually pop into and out of the imagery.

13. If there is no requirement for blanking imagery (i.e., if the sentence following (7) was deleted), delete the sentence following (13).

***Process Guidance:** The various simulator events and activities are often not well defined early in the development process. Intelligent decisions regarding the conditions under which the visual imagery should be blanked (see requirements guidance 7 above) will require knowing exactly what the various simulator events and activities will entail, along with how the device is to be used. It may be advisable to make the requirement in blank (7b) "TBD" and define a statement of work task to rewrite it later. Additional guidance can be found in "Simulator Sickness, Field Manual Mod 3", published in August 1988 by the Naval Training Systems Center (now Naval Air Warfare Center, Training Systems Division), Code 7, 12350 Research Parkway, Orlando FL 32826-3224.*

EXAMPLES

Example 1. Visual system requirement consistent with a Level D helicopter simulator.

3.7.2.1 Visual System. The visual system shall process the environment data and display perspectively-correct imagery in accordance with the requirements of this specification. Daylight, dusk, and night out-the-window (OTW) imagery shall be provided. Daylight OTW imagery shall be in full color with scene content comparable in detail to that produced by 4000 edges or 2000 polygons. Dusk OTW imagery shall be in color with scene content sufficient to enable identification of a visible horizon and typical terrain characteristics such as fields, roads, and bodies of water. OTW visual scene content shall be sufficient to recognize significant fixtures and to successfully assess sink rate and depth perception during low-level operations. The visual scene shall accurately portray the synthetic environment in relationship to the simulated aircraft's attitude and position. Temporal and spatial aliasing shall be reduced to non-distracting levels without introducing distracting color variations. All requirements of this specification shall be met without readjustment of controls affecting image quality.

4.2.1.7.2.1 Verification of Visual Systems. This requirement shall be verified by demonstration and analysis. All required visual system imagery shall be verified in conjunction with the following demonstrations of Appendix 2 of AC-120-63 "Helicopter Simulator Qualification":

Test 4b Visual system color
Test 4d Visual display focus and intensity

Test 4e Visual attitude vs. simulator attitude indicator (pitch and roll of horizon)

Visibility definition, airport scene content, and flight compatibility shall be demonstrated in accordance with AC-120-63 Appendix 3 Test 2. Analysis during design reviews shall verify that visual system capacity is consistent with the requirement.

Example 2. Visual system requirement for a military airplane simulator nominally meeting Level D standards. A large number of entities are required to simultaneously interact with the simulated aircraft, and the synthetic environment scene complexity is comparatively rich. It is desired to realize the full capability of the image generator, even though that may mean that it will at times be subject to overload. Since content-rich imagery will be displayed in a wide field of view, the potential of the visual system inducing simulator sickness is a concern.

3.7.2.1 Visual System. The visual system shall process the environment data and display perspectively-correct imagery in accordance with the requirements of this specification. Daylight, dusk, and night out-the-window (OTW) imagery shall be provided. Daylight OTW imagery shall be in full color with scene content comparable in detail to that produced by 4000 edges or 1000 polygons. Dusk OTW imagery shall be in color with scene content sufficient to enable identification of a visible horizon and typical terrain characteristics such as fields, roads, and bodies of water. OTW visual scene content shall be sufficient to recognize significant fixtures and to successfully assess sink rate and depth perception during low-level operations. The visual scene shall accurately portray the synthetic environment in relationship to the simulated aircraft's attitude and position. Temporal and spatial aliasing shall be reduced to non-distracting levels without introducing distracting color variations. Load and environment data processing shall be managed to assure that manifestations of distracting overload conditions such as breakup, dropout, streaking, flashing, or discontinuities in any part of the visual scene are separated in time by at least five minutes, and that the duration of any such overload condition does not exceed five consecutive display frames. In those situations where visual system load management necessitates that the number of entity platforms portrayed be less than the total number instantiated, the most critical subset of the instantiated entity platforms shall be portrayed. OTW and Night Vision Goggle (NVG) imagery shall be blanked during aircraft position set and reset activities and when freeze is commanded; blanking shall be overridden upon command. All requirements of this specification shall be met without readjustment of controls affecting image quality.

4.2.1.7.2.1 Verification of Visual Systems. This requirement shall be verified by demonstration and analysis. All required visual system imagery shall be verified in conjunction with the following demonstrations of the "Airplane Flight Simulator Evaluation Handbook":

Section 4b Visual system color
Section 4b Visual display focus and intensity
Section 4b Visual attitude correlation
Section 4d Visibility definition
Section 4e Airport scene content
Section 4g Flight compatibility

Analysis during design reviews shall verify that visual system capacity is consistent with the requirement. Analysis during design reviews and demonstration at maximum visibility over the full dynamic range of the simulated aircraft's translational and rotational rates shall verify that the visual system has adequate capacity for real-time retrieval and caching of environment data and the monitoring and controlling of overload conditions. Analysis during design reviews and demonstration with the maximum number of instantaneously interacting entities instantiated shall verify that the visual system portrays the most critical entities. Demonstration shall verify that the required imagery is blanked in accordance with the requirement.

3.7.2.1.1 Field of View. The visual system shall present a (1)continuous minimum (2)collimated field of view of __3__ degrees horizontal and __4__ degrees vertical per pilot seat, as measured from the design

eyepoint corresponding to the display channel. (5)A wide-angle display system shall provide cross-cockpit viewing with a minimum of __5a__ degrees total horizontal field of view. (6)The angle subtended by gaps between mosaicked display channels shall not be greater than __6a__ degrees as measured at each pilot seat's design eyepoint. (7)The position of the horizontal field of view shall be __7a__. (8)The position of the vertical field of view shall be __8a__. The OTW imagery shall be displayed at each pilot seat simultaneously. __9__.

4.2.1.7.2.1.1 Verification of Field of View. This requirement shall be verified by test. The extent of (10)the/each field of view (11)and the angle subtended by gaps between mosaicked display channels shall be verified using a theodolite located at the design eyepoint of each pilot's seat.

RATIONALE

The display field of view requirement is probably the single most important parameter affecting simulator visual system design. The aircraft being simulated, the positions of crew members using the display, and the tasks being trained must all be considered to determine the required field of view. In addition to the field of view, it is also usually necessary to specify the best placement or positioning of the field of view for the specific application.

Requirements Guidance:

1. A continuous field of view will have no gaps between display channels, and will have image continuity across display channels. If a continuous display is not required, delete the word "continuous" following (1). Continuous displays are not required for airplane and helicopter simulators below Level C.

2. If a collimated display is not required, delete the word "collimated" following (2). Collimated displays are not required for airplane and helicopter simulators below Level C. For Level C and D helicopter simulators, replace the word "collimated" with "collimated (or equivalent)".

3. Insert the required horizontal field of view for each pilot seat in blank (3). Level C and D airplane simulators require a minimum of 75 degrees. Airplane simulators below Level C require 45 degrees. Level C and D helicopter simulators require 150 degrees. Level B helicopter simulators require 75 degrees.

4. Insert the required vertical field of view for each pilot seat in blank (4). All commercial airplane simulators require a minimum of 30 degrees. Level D helicopter simulators require 60 degrees. Level C helicopter simulators require 40 degrees. Level B helicopter simulators require 30 degrees.

5. If a wide-angle display is not being used, delete the sentence following (5). Otherwise, put the required wide-angle horizontal field of view in blank (5a). Level C and D airplane simulators allow (but do not require) a wide-angle display providing 150 degrees horizontal field of view; with a wide-angle display, 75 degrees horizontal field of view per pilot seat is still a requirement. This sentence can be deleted for Level C and D helicopter simulators since it is redundant to the per-pilot-seat requirement in blank (3).

6. If a continuous display across the field of view is required (i.e., the word "continuous" following (1) was retained), then delete the sentence following (6). Otherwise, specify the maximum acceptable gap width in blank (6a).

7. If the position of the horizontal field of view is not to be specified, delete the sentence following (7). Otherwise, specify where the field of view is to be positioned in blank (7a) using verifiable language -- i.e., provide a specific location or locations (it may be desirable to be able to slue the position), do not use terms such as "optimum"; unless the required position is clearly established early in the acquisition process, it is probably best to initially leave this "TBD", and have the contractor later select a location or locations best suited for the application. Level C and D helicopter simulators require that the horizontal

field of view be "centered on the zero degree azimuth line relative to the aircraft fuselage." Otherwise, the commercial simulator standards do not specify a horizontal field of view position.

8. If the position of the vertical field of view is not to be specified, delete the sentence following (8). Otherwise, specify where the field of view is to be positioned in blank (8a) using verifiable language -- i.e., provide a specific location or locations (it may be desirable to be able to slue the position), do not use terms such as "optimum"; unless the required position is clearly established early in the acquisition process, it is probably best to initially leave this "TBD", and have the contractor later select a location or locations best suited for the application. The commercial simulator standards do not specify a vertical field of view position.

9. In blank (9), specify any additional requirement. For example, to conform to Level D helicopter simulator standards, the following would be inserted in blank (9): "The visual system shall additionally present fields of view that represent the OTW scene as viewed by the pilots through the chin windows of the helicopter."

Verification Guidance: *Field of view measurements should be made at the appropriate design eyepoints, and include the field of view hidden by canopy bow and other optical barriers. There is no formal verification procedure for the field of view in the regulatory commercial simulator evaluation standards. Nonetheless, any requirement stated in this specification must have a corresponding verification paragraph.*

10. Select either "the" or "each" in "the/each" depending on which is appropriate.

11. If the sentence following (6) is deleted (i.e., no maximum gap width is specified), also delete the phrase "and the angle subtended by gaps between mosaicked display channels" following (11).

Process Guidance: *If there are any "TBD"s, the contractor should be tasked in the statement of work to update this specification once the values for the TBDs are established.*

EXAMPLES
Field of view requirement consistent with a Level D helicopter simulator.

3.7.2.1.1 Field of View. The visual system shall present a continuous minimum collimated (or equivalent) field of view of 150 degrees horizontal and 60 degrees vertical per pilot seat, as measured from the design eyepoint corresponding to the display channel. The position of the horizontal field of view shall be centered on the zero degree azimuth line relative to the aircraft fuselage. The OTW imagery shall be displayed at each pilot seat simultaneously. The visual system shall additionally present fields of view that represent the OTW scene as viewed by the pilots through the chin windows of the helicopter.

3.7.2.1.2 Light Points. Light point types, appearance, and directional characteristics shall be simulated in accordance with the requirements of the synthetic environment section of this specification, and shall vary in brightness as a function of range and visibility. Each light-point-type string shall have independently commanded intensity and on/off activity. The visual system shall generate a minimum of __1__ light points per frame for night/dusk scenes (2)and __2a__ light points per frame for day scenes (3)within the total field of view. (4)Light point capacity shall be in addition to the surface capacity of the image generator. (5)Light point size shall not be greater than __5a__ arc minutes. (6)Light point contrast ratio shall not be less than __6a__.

4.2.1.7.2.1.2 Verification of Light Points. This requirement shall be verified by analysis, (7)demonstration, and test. Engineering analysis during the design process shall verify the theoretical light point capacity of the image generator. A test pattern consisting of a mixture of lights from the different light-point-type strings shall be used to test the system light point capacity. The pattern shall be portrayed statically to permit verification of the number of lights, and dynamically to verify that different

light-point-type strings exhibit the required characteristics. (7)Analysis of the results of demonstrations conducted by flying the simulated aircraft through the database shall verify the required light point capacity in addition to the surface capacity of the image generator. (8)Light point size shall satisfy the requirement when measured in a test pattern consisting of a single row of light points reduced in length until modulation is just discernible; a row of 40 lights shall subtend an angle of __8a__ degrees or less. (9)Light point contrast ratio shall satisfy the requirement when a one-degree or larger square filled (i.e., light point modulation is just discernible) with light points is compared to the adjacent background.

RATIONALE

Requirements Guidance: *The requirement for light points -- and the number of lights required -- is dependent upon the tasks to be trained or practiced. Light point generation requires some dedicated processing, and may not be available in lower-end image generators that might otherwise be adequate to support the simulation requirements.*

1. Fill in blank (1) with the minimum number of light point sources required for night/dusk scenes. No specific capacity is required for Level B or C airplane or helicopter simulators. A typical number used in military simulators is 2500 light points per frame. The light point capacity for Level D airplane and helicopter simulators is 4000 light points per frame.

2. Delete the phrase "and __2a__ light points per frame for day scenes" following (2) if there is no requirement for light points in day scenes. This is not a requirement for commercial aviation simulators, but point lights may be important in some military applications. If this requirement is retained, fill in blank (2a) with the minimum number of light point sources required for day scenes; a typical number used in military simulators is 750 light points per frame.

3. It may be necessary to tailor the paragraph to specify the light point capacity on a channel basis (in addition to, or instead of, the total field-of-view requirement) in order to optimize the light point distribution for the specific application and simulator.

4. Some state-of-the-art image generators can produce in excess of 4000 light points in addition to their surface capacity. Some systems, however, trade surface (polygon) processing capacity for light point processing capacity. This trade-off is perfectly acceptable for applications where the joint light point and surface capacity will support the simulation objectives. Level D airplane and helicopter simulator requirements can be met so long as sufficient surface capacity is retained to enable identification of typical terrain characteristics (fields, roads, bodies of water, etc.) in dusk scenes, observe runway markings within range of landing lights in night scenes, and assess sink rate during takeoff and landing operations in general. If a trade-off of surface processing capacity for light point processing capacity is acceptable, delete the sentence following (4).

5. Level C and D airplane simulators and Level D helicopter simulators require that light point size not be greater than 6 arc minutes (i.e., a row of 40 lights will not exceed a 4 degree angle; this is equivalent to a light point resolution of 3 arc minutes). Light point size is not explicitly specified for lower-level simulators. If light point size is not an explicit requirement, delete the sentence following (5). Otherwise, fill in blank (5a) with the required value.

6. Level C and D airplane simulators and Level D helicopter simulators require that light point contrast ratio not be less than 25:1. Light point contrast ratio is not explicitly specified for lower-level simulators. If light point contrast ratio is not an explicit requirement, delete the sentence following (6). Otherwise, fill in blank (6a) with the required value.

Verification Guidance:

7. If the light point capacity is not required to be in addition to the surface capacity of the image generator (see 4 above), delete the requirement for demonstration, and delete the sentence following (7).

8. If light point size is not an explicit requirement, delete the sentence following (8). Otherwise, fill blank (8a) with the appropriate value (e.g., if maximum light point size is 6 arc minutes, a row of 10 lights will subtend an angle of one degree or less; a row of 40 lights shall subtend an angle of 4 degrees or less). This test requirement conforms to the requirement for Level C and D airplane simulators and Level D helicopter simulators.

9. If light point contrast ratio is not an explicit requirement, delete the sentence following (9). This test requirement conforms to the requirement for Level C and D airplane simulators and Level D helicopter simulators.

EXAMPLES
Example 1. Light points requirement consistent with a Level D flight simulator (some flicker of brightly lit objects in dusk/night scenes is permitted so that the refresh rate can be lowered for dusk/night illumination levels; see the example for paragraph 3.7.2.1.12 "Display Refresh and Update Rates").

3.7.2.1.2 Light Points. Light point types, appearance, and directional characteristics shall be simulated in accordance with the requirements of the synthetic environment section of this specification, and shall vary in brightness as a function of range and visibility. Each light-point-type string shall have independently commanded intensity and on/off activity. The visual system shall generate a minimum of 4000 light points per frame for night/dusk scenes within the total field of view. Light point size shall not be greater than six arc minutes. Light point contrast ratio shall not be less than 25:1.

4.2.1.7.2.1.2 Verification of Light Points. This requirement shall be verified by analysis and test. Engineering analysis during the design process shall verify the theoretical light point capacity of the image generator. A test pattern consisting of a mixture of lights from the different light-point-type strings shall be used to test the system light point capacity. The pattern shall be portrayed statically to permit verification of the number of lights, and dynamically to verify that different light-point-type strings exhibit the required characteristics. Light point size shall satisfy the requirement when measured in a test pattern consisting of a single row of light points reduced in length until modulation is just discernible; a row of 40 lights shall subtend an angle of four degrees or less. Light point contrast ratio shall satisfy the requirement when a one-degree or larger square filled (i.e., light point modulation is just discernible) with light points is compared to the adjacent background.

Example 2. Light point requirement where light point capability is required for daylight scenes as well as dusk/night illumination levels. The required light point capacity is independent of, and in addition to, the surface capacity of the image generator.

3.7.2.1.2 Light Points. Light point types, appearance, and directional characteristics shall be simulated in accordance with the requirements of the synthetic environment section of this specification, and shall vary in brightness as a function of range and visibility. Each light-point-type string shall have independently commanded intensity and on/off activity. The visual system shall generate a minimum of 2500 light points per frame for night/dusk scenes and 750 light points per frame for day scenes within the total field of view. Light point capacity shall be in addition to the surface capacity of the image generator. Light point size shall not be greater than six arc minutes. Light point contrast ratio shall not be less than 25:1.

4.2.1.7.2.1.2 Verification of Light Points. This requirement shall be verified by analysis, demonstration, and test. Engineering analysis during the design process shall verify the theoretical light point capacity of the image generator. A test pattern consisting of a mixture of lights from the different light-point-type strings shall be used to test the system light point capacity. The pattern shall be portrayed statically to permit verification of the number of lights, and dynamically to verify that different light-point-type strings exhibit the required characteristics. Analysis of the results of demonstrations conducted by flying the simulated aircraft through the database shall verify the required light point capacity in addition to the surface capacity of the image generator. Light point size shall satisfy the requirement when measured in a test pattern consisting of a single row of light points reduced in length until modulation is just discernible; a row of 40 lights shall subtend an angle of four degrees or less. Light point contrast ratio

shall satisfy the requirement when a one-degree or larger square filled (i.e., light point modulation is just discernible) with light points is compared to the adjacent background.

3.7.2.1.3 Levels of Occulting. The visual system shall provide a minimum of __1__ levels of occulting through each channel.

4.2.1.7.2.1.3 Verification of Levels of Occulting. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

This requirement shall be verified by demonstration in accordance with the procedure of Section 4b "Occulting levels demonstration" of the "Airplane Flight Simulator Evaluation Handbook".

-OR-

This requirement shall be verified by demonstration. The demonstration scene shall portray a series of __2__ solid objects positioned such that each object occludes a portion of the object behind it. All non-occluded portions of the objects used for the demonstration shall be in view in each channel. The types of objects depicted in the demonstration scene shall permit an observer to quickly verify the requisite number of occulting levels.

RATIONALE
Requirements Guidance: *In blank (1), specify the required number of occulting levels. All levels of commercial airplane and helicopter simulators require a minimum of ten levels of occulting.*

Verification Guidance: *Choose either the first or second verification paragraph alternative.*

The first alternative can be applied to any level airplane or helicopter simulator, but is written specifically for ten levels of occulting.

The second alternative specifies the verification procedure required for a generic number of occulting levels, and uses a procedure that parallels that of Section 4b "Occulting levels demonstration" of the "Airplane Flight Simulator Evaluation Handbook". If this alternative is used, specify the required number of occulting levels in blank (2); this should be the same number as inserted in blank (1).

3.7.2.1.4 Brightness. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

The highlight brightness of a maximum intensity area in a daylight out-the-window (OTW) scene shall not be less than __1__ footlamberts measured at the design eye point. Daylight OTW scenes shall produce simulator cockpit ambient lighting in accordance with the following two criteria. The luminance of an approach plate at knee height at the pilot's station shall not be less than __2__ footlamberts. The luminance of the pilot's face shall not be less than __3__ footlamberts.

-OR-

The highlight brightness of a maximum intensity area in a daylight out-the-window (OTW) scene shall not be less than __4__ footlamberts measured at the design eye point. Brightness uniformity from the center to within five degrees of a display channel's edge shall be within __5__ percent of that display channel's center highlight brightness. (6)The brightness uniformity from any display channel's edge to an adjacent display channel's edge shall not vary more than __6a__ percent.

4.2.1.7.2.1.4 Verification of Brightness. This requirement shall be verified by (7)test. A raster-drawn test pattern filling the entire OTW visual scene shall be used. The test pattern shall consist of a matrix of maximum-black and maximum-white squares no larger than 10 degrees and no smaller than 5 degrees in each display channel, with a maximum-white square in the center of each display channel. A one-degree spot photometer shall be used to measure the brightness of the center white square of each display

channel to verify highlight brightness. (8)The photometer shall be used to verify conformance to the cockpit ambient lighting criteria. (9)Extreme high and low brightness photometer measurements made of randomly selected maximum-white squares shall be used to verify brightness uniformity.

RATIONALE

The higher the brightness, the better the eye can see detail for any given resolution and contrast ratio. Brightness and brightness uniformity are important characteristics of any display system. These are especially critical in projection displays since the act of producing an image on a large screen seems to be at odds with good brightness and uniformity performance.

Requirements Guidance: *Choose either the first or second requirement alternative -- or tailor a combination of both -- according to what is required for the specific application.*

The first alternative is consistent with the brightness requirement for a Level D airplane or helicopter simulator (there is no explicit brightness requirement for lower-level commercial simulators). This first alternative does not address brightness uniformity.

The second alternative is more generic. It provides a means of specifying minimum brightness levels for simulators below Level D. It also provides a means of specifying brightness uniformity.

If the first alternative is selected:

1. Specify the minimum highlight brightness for daylight scenes in blank (1). Level D airplane and helicopter simulators require no less than 6 footlamberts measured at the pilot's eye position (design eye point). Keep in mind that 6 footlamberts is difficult to attain on some commercially available systems. For example, typical highlight brightness in a visual system using a unity-gain dome display is 0.5 footlamberts. The background raster on a pancake window display typically has a highlight brightness of 1.5 to 2.0 footlamberts. On the other hand, 6 footlamberts is not a problem for direct-view or beamsplitter/mirror display systems.

Specifications for absolute peak brightness sometimes are in excess of what the equipment can deliver. Brightness capabilities may at times be exaggerated, and these exaggerations tend to find their way into specifications. It is better to specify a realistic, albeit somewhat smaller, peak brightness level and have a number that more accurately represents the day-to-day operating level of the system.

2. Level D airplane and helicopter simulator standards impose the requirement that, "The daylight visual scene must be part of a total daylight cockpit environment which at least represents the amount of light in the cockpit on an overcast day. ...For daylight scenes, such ambient lighting shall not 'washout' the displayed visual scene nor fall below 17 cd/m² (5 foot-Lamberts) of light as reflected from an approach plate at knee height at the pilot's station and/or 7 cd/m² (2 foot-Lamberts) of light as reflected from the pilot's face." To meet Level D standards, specify 5 footlamberts in blank (2).

3. Refer to the requirements guidance in 2 above. To meet Level D standards, specify 2 footlamberts in blank (3).

If the second alternative is selected:

4. Specify the minimum highlight brightness for daylight scenes in blank (4). Refer to requirements guidance 1 above.

5. Fill in blank (5) with a percentage. Most visual displays have an inherent brightness rolloff away from the center of a channel. Often electronic corrections are made in an attempt to make a uniform picture. A 20 percent brightness uniformity is very good. The specification should never permit more than 50 percent rolloff.

6. This requirement is applicable to mosaicked display or projection systems. If not applicable, delete the sentence following (6). Otherwise, fill in blank (6a) with a percentage. Edge brightness mismatch across display channels is easy for the eye to detect because the brightness changes abruptly. The center brightness of each display is usually adjustable, and matching can be done with a photometer. Practical considerations support matching edge brightness across display channels to within 20 percent. The specification should never permit more than 50 percent mismatch.

NOTE REGARDING BRIGHTNESS AND BRIGHTNESS UNIFORMITY:

The eye's logarithmic brightness response permits substantial brightness variation without becoming objectionable. A 2:1 brightness variation across an area is required to ensure detection. In some cases it may be better to allow center-to-center display channel tolerances to deteriorate somewhat if an improvement in edge-to-edge matching can be achieved. This is an important consideration in an air-to-air combat simulator where the pilot may track an aircraft traveling from one channel to another.

***Verification Guidance:** The verification paragraph provides a procedure for verifying conformance to Level D airplane or helicopter simulator standards. The verification procedure is contained in the Appendix 1 of AC-120-40C and AC-120-63, rather than Appendix 2 or 3 of these documents. Consequently, while Section 4b "Daylight scene display brightness" of the "Airplane Flight Simulator Evaluation Handbook" and Appendix 2 of AC-120-63 "Helicopter System Qualification" contain evaluation criteria, they do not include any real test procedures. Therefore, it is recommended that the verification procedures be directly specified in this paragraph rather than by reference to the commercial regulatory documents.*

While the verification paragraph as written captures the essence of the Level D simulator standards, there is a subtle -- but important -- difference. The highlight brightness as defined for Level D simulators goes beyond the simple maximum-white and maximum-black checkerboard pattern specified herein. The Level D standard explicitly permits superimposition of a highlight on the center white square using calligraphic capabilities to enhance raster brightness (although the use of light points is ruled out). This would result in higher values of highlight brightness than the test procedures provided herein. It is felt, however, that the test procedure provided herein provides a better measure of day-to-day operational performance.

7. There is no good way to subjectively evaluate display brightness or brightness uniformity. An objective test is the best approach for assuring compliance. However, there are display configurations (e.g., helmet-mounted displays) for which special test rigs and procedures would be required in order to accurately verify conformance to the brightness and brightness uniformity requirements. In some such instances, it might be practical to verify that the display system can satisfy the requirement via "analysis"; if such is the case, replace the word "test" following (7) with "analysis" or "test and analysis" as appropriate. Regardless of whether "test" or "analysis" is to be employed as the verification means, this verification paragraph will have to be tailored to reflect any specialized test or analysis procedure.

8. If there is no requirement regarding cockpit ambient lighting (e.g., if the first alternative requirement paragraph was not used), delete the sentence following (8).

9. If there is no requirement regarding brightness uniformity (e.g., if the second alternative requirement paragraph was not used), delete the sentence following (9).

EXAMPLES
Example 1. Brightness requirement consistent with a Level D flight simulator.

3.7.2.1.4 Brightness. The highlight brightness of a maximum intensity area in a daylight out-the-window (OTW) scene shall not be less than six footlamberts measured at the design eye point. Daylight OTW scenes shall produce simulator cockpit ambient lighting in accordance with the following two criteria. The

luminance of an approach plate at knee height at the pilot's station shall not be less than five footlamberts. The luminance of the pilot's face shall not be less than two footlamberts.

Example 2. Brightness requirement including a specification for brightness uniformity. A wide-angle display utilizing five projectors is proposed.

3.7.2.1.4 Brightness. The highlight brightness of a maximum intensity area in a daylight out-the-window (OTW) scene shall not be less than five footlamberts measured at the design eye point. Brightness uniformity from the center to within five degrees of a display channel's edge shall be within 20 percent of that display channel's center highlight brightness. The brightness uniformity from any display channel's edge to an adjacent display channel's edge shall not vary more than 20 percent.

3.7.2.1.5 Contrast Ratio. Across the entire field of view of each display, the contrast ratio shall not be less than __1__ measured at the design eyepoint. Contrast shall be maintained in each display individually when all channels are displaying a typical daylight scene. Contrast shall be maintained in each display under normal operational ambient light conditions.

The contrast ratio (CR) shall be defined as: CR = W/B where,

W = White brightness (measured in footlamberts)

B = Black brightness (measured in footlamberts)

4.2.1.7.2.1.5 Verification of Contrast Ratio. This requirement shall be verified by (2)test. A raster-drawn test pattern filling the entire OTW visual scene (all channels) shall be used. The test pattern shall consist of a matrix of maximum-black and maximum-white squares no larger than 10 degrees and no smaller than 5 degrees in each display channel, with a maximum-white square in the center of each display channel. A one-degree spot photometer shall be used to measure the brightness of the center white square of each display channel and the brightness of any adjacent dark square. White and black brightness photometer measurements shall be made of randomly selected white squares and adjacent black squares across the entire field of view. The contrast ratio shall be computed from each white-black brightness-measurement-pair to verify compliance with the requirement.

RATIONALE
The contrast ratio is an important display parameter that describes the ratio of the brightest white to the blackest black. It works in conjunction with brightness and resolution characteristics to determine the quality of the displayed image. A good contrast ratio provides a sharper-looking display.

Requirements Guidance:

1. Fill in blank (1) with the required contrast ratio. A contrast ratio of 30:1, combined with decent resolution and brightness characteristics, will yield an excellent display image. This is not always a practical value, however, since many visual display systems will not support a 30:1 contrast ratio -- and other constraints and requirements must be considered. Level D airplane and helicopter simulators require a contrast ratio not less than 5:1 (this is equivalent to 4:1 under the traditional Air Force definition; see the note below). There is no explicit contrast ratio requirement for lower-level commercial simulators.

NOTE REGARDING DEFINITION OF CONTRAST RATIO

There are several common definitions of contrast ratio, and different results are obtained using the different definitions. Let W be the maximum-white brightness and B be the maximum-black brightness measured under test conditions. Let CR be the contrast ratio. Assume for example that W=6 footlamberts and B=0.5 footlamberts. Regulatory Agencies have adopted the definition used by Optics Companies (this definition has also been adopted in this revision of the Air Force Guide Specification) that computes CR=W/B, with a result of 12:1. Terminal manufacturers use CR=(W+B)/B, with the result

of 13:1. The traditional Air Force definition was CR=(W-B)/B, which degraded contrast for poor black level; the result for the example would be 11:1. ADOPTION OF THE DEFINITION USED BY REGULATORY AGENCIES REQUIRES A TRANSLATION OF CONTRAST RATIO VALUES ESTABLISHED UNDER THE TRADITIONAL AIR FORCE DEFINITION. That is, a value for contrast ratio under the traditional Air Force definition would be equivalent to that value incremented by one under the current regulatory agency definition (i.e., ((W-B)/B)+1=W/B). This distinction may not be significant for large values (e.g., 30:1), but it becomes more important at smaller values (e.g., 5:1 under the traditional Air Force definition would be equivalent to 6:1 under the current regulatory agency definition).

Verification Guidance:

2. There is no good way to subjectively evaluate display contrast. An objective test is the best approach for assuring compliance. However, there are display configurations (e.g., helmet-mounted displays) for which special test rigs and procedures would be required in order to accurately verify conformance to the contrast ratio requirement. In some such instances, it might be practical to verify that the display system can satisfy the requirement via "analysis"; if such is the case, replace the word "test" following (2) with "analysis" or "test and analysis" as appropriate. Regardless of whether "test" or "analysis" is to be employed as the verification means, this verification paragraph will have to be tailored to reflect any specialized test or analysis procedure.

EXECUTION AND EVALUATION GUIDANCE NOTES:

The test conditions are extremely critical for contrast. Contrast can be significantly affected by changing the size of the target window used. Light from the test pattern can bounce off reflective surfaces and degrade the contrast ratio. Typically the larger the test pattern, the poorer the measured contrast. When testing, ensure that the test pattern size is as stated in the requirement.

A problem may be encountered when measuring contrast near a black-to-white transition with a photometer. The photometer's measurement area is in the center of the field of view as indicated by a dark spot. Ideally the photometer measures only this area and ignores the area outside the spot. Internal reflections within the photometer's optics may cause a slightly high reading of the black area if the white area is also within the photometer's total field-of-view. The higher the visual system's contrast, the more likely it is that this effect will become noticeable. Judgment must be exercised when making the black brightness measurement.

3.7.2.1.6 Resolution. When viewed from the design eyepoint, the horizontal and vertical resolution of displayed imagery shall comply with the following. An optical line pair (OLP) subtending a visual angle of __1__ arc-minutes shall be resolvable __2__. __3__.

4.2.1.7.2.1.6 Verification of Resolution. This requirement shall be verified by analysis and demonstration. (4)A test pattern in the database that is processed in the identical way as the operational database shall be used to demonstrate the required resolution. Analysis shall verify that the test pattern and viewing distances used in the demonstration result in the subtense of visual angles corresponding to the required resolution.

RATIONALE

The resolution of the displayed imagery determines to a large extent how much detail is visible and how sharp the picture appears. Resolution will generally be different in the horizontal and vertical directions. Resolution is a dominant parameter and will often drive the selection of both the display system and the image generator.

Resolution requirements apply to all contributions of the visual system, including:

Field-of-view per display channel.
Number of pixels per display channel.
Characteristics of the image generator anti-aliasing filter.

Resolution of the display system at specified brightness.
Bandwidth of the display system's video amplifier chain.
Display optics.

Requirements Guidance:

The smallest visible object in a displayed scene (termed a resolution element or "rexel") is one-half of the smallest resolvable optical line pair (OLP). The contrast modulation of the OLP needs to be about 10% or greater in order that the OLP be resolvable. (Note that a rexel is not the same as a pixel; in fact, one consideration in selecting components for a display system is the maximization of the number of rexels per pixel.)

The required resolution can be roughly determined by determining the smallest object that needs to be detected and the range at which it needs to be detected (example: an eighteen-inch UHF antenna on a refueling tanker needs to be detected at 100 feet). The rexel subtense in angular units can then be determined from the geometry (example: one rexel subtends arctangent{1.5 feet/100 feet} = 52 arc-minutes). Two adjacent rexels comprise one OLP (e.g., one OLP subtends 104 arc-minutes).

1. In blank (1), specify the resolution required for the center of each display in arc-minutes per OLP. Level D airplane and helicopter simulators (and lower-level airplane and helicopter simulators that have a daylight scene capability) require a resolution of 6 arc-minutes per OLP.

2. Select one of the following two alternatives:

Requirements Alternative 1.
For the commercial requirement for Level D airplane and helicopter simulators (and lower-level airplane and helicopter simulators that have a daylight scene capability) put the following in blank (2): "throughout the observer's field of view."

Requirements Alternative 2.
Since resolution is highest in a display channel center and rolls off near the edges, it may be desirable in some applications not to require that the resolution be the same throughout the entire field of view -- but to tailor the requirement for center-channel and the display edges separately. To control resolution in the center and near the display edges separately, put the following in blank (2): "within a circle having a diameter equal to picture height and circumscribed about each display center. Elsewhere, an OLP subtending a visual angle of __2a__ arc-minutes shall be resolvable."

In blank (2a), insert the acceptable resolution near the display edges. In a System Requirements Document, this value may be left "TBD" to be supplied by the offeror even if the required resolution for the display center is filled in.

3. For systems that include an area-of-interest (AOI) display or the display of other inserted or projected high-resolution objects, the resolution of the AOI or high-resolution objects must be specified separately in blank (3).

Verification Guidance:

4. For computer-generated image systems, verification should be accomplished with a test pattern in the database that is processed in the identical way as the operational environment database; the verification wording in the sentence following (4) is equivalent to that found in commercial regulatory documents. For camera-model or pure optical systems, the sentence following (4) should be replaced with, "A resolution test chart shall be substituted for the model."

EXAMPLES
Example 1. Resolution requirement consistent with a Level D flight simulator.

3.7.2.1.6 Resolution. When viewed from the design eyepoint, the horizontal and vertical resolution of displayed imagery shall comply with the following. An optical line pair (OLP) subtending a visual angle of six arc-minutes shall be resolvable throughout the observer's field of view.

Example 2. Resolution requirement that allows for lower resolution nearer the display edges.

3.7.2.1.6 Resolution. When viewed from the design eyepoint, the horizontal and vertical resolution of displayed imagery shall comply with the following. An optical line pair (OLP) subtending a visual angle of four arc-minutes shall be resolvable within a circle having a diameter equal to picture height and circumscribed about each display center. Elsewhere, an OLP subtending a visual angle of six arc-minutes shall be resolvable.

3.7.2.1.7 Image Continuity. Imagery shall be continuous across display channel boundaries. Image mismatch shall not exceed __1__ degrees anywhere along the display channel boundaries.

4.2.1.7.2.1.7 Verification of Image Continuity. This requirement shall be verified by test. A small test pattern or target shall be displayed along an edge between two adjacent displays. The test pattern or target shall be observed from each design eyepoint at several points along the display boundaries in order to identify the largest apparent mismatches. The largest apparent mismatches shall then be measured using a theodolite set up at the corresponding design eyepoint. Both the horizontal and vertical offset of the test image shall be measured. The resultant error shall be computed as the square root of the sum of the squares of the horizontal and vertical offsets. This error shall not exceed the specified tolerance.

RATIONALE
On visual systems that require mosaicked display channels, edge misregistration of the image across channels needs attention. There may be instances where the independent distortion correction applied to two side-by-side channels is in different directions, and leads to an unacceptable discontinuity of the image across the channel boundaries.

Commercial regulatory standards do not explicitly specify a tolerance or measure misregistration, but instead rely on an unwritten understanding that display quality must be reasonable if the simulator is to be qualified.

Requirements Guidance:

1. In blank (1), insert the acceptable tolerance for image misregistration. The image continuity requirement will vary depending upon the training task. Image continuity across channels is especially important in simulators that require tracking the target as it slues across the displayed scene, such as with air-to-ground or air-to-air combat tasks. Visual systems with wide gap angles are more tolerant of image discontinuities..

A typical tolerance for image continuity is 0.5 degrees.

Verification Guidance:

EXECUTION AND EVALUATION GUIDANCE NOTES:
Observe the target as it crosses the window boundaries at several points. The eye is pretty good at detecting mismatches. Measurements are minimized by checking only those areas that subjectively appear to have the worst error.

Process Guidance: *If the misregistration tolerance is "TBD", the contractor should be tasked in the statement of work to update this specification once the value is established.*

3.7.2.1.8 Geometric Distortion. The geometric distortion in each display channel shall not be greater than __1__ percent of the picture height within a circle of diameter equal to the picture height, and shall not be greater than __2__ percent of the picture height outside a circle of diameter equal to the picture height. Displays shall be aligned such that the maximum distortion anywhere within the field of view shall not be greater than __3__ percent of the picture height. (4)Geometric distortion in the area __4a__ shall not be greater than __4b__ percent of the picture height.

4.2.1.7.2.1.8 Verification of Geometric Distortion. This requirement shall be verified by analysis and test. A test pattern consisting of a minimum of ten rows by ten columns of equal-angularly spaced dots shall be used. A theodolite, placed at the design eyepoint, shall be used to measure the angular position of the dots in the display. The theoretical angular position of the dots shall be substantiated by analysis. The geometric distortion shall be computed as the angular error between a dot's measured position and theoretical position expressed as a percentage of total angular picture height. A sufficient number of points shall be chosen to ensure compliance throughout the field of view.

RATIONALE

Geometric distortion occurs in visual systems due to nonlinearities in the displays and optics. Geometric distortion is defined as an error in geometric position expressed as a percentage of picture height, where the error and picture height are measured in degrees.

Geometric distortion should always be referenced to picture height. On a previously acquired visual system, the distortion was referenced to the angle away from the center, with the intent on minimizing distortion in the HUD area. This led to a literal interpretation of zero distortion tolerance in the center of the picture -- which is impossible to achieve. Special cases are better handled as recommended in 4 below.

Commercial regulatory standards do not explicitly specify a tolerance or measure geometric distortion, but instead rely on an unwritten understanding that display quality must be reasonable if the simulator is to be qualified.

Requirements Guidance:

The amount of distortion that can be tolerated varies depending upon the specific application, and sometimes on the field of view. The values provided below tend to be on the high side. Do not specify tolerances greater than these values:

1. Within a circle of diameter equal to the picture height, distortion in any display should never exceed two percent of the picture height.

2. Outside a circle of diameter equal to the picture height, distortion in any display should never exceed three percent of the picture height.

3. The maximum distortion anywhere within the field of view should never exceed four percent of the picture height.

4. In special cases where tolerances need to be tighter over a specific area (such as for a HUD simulation), it is best to specify a separate tolerance for that particular area of the display. If there are no areas requiring tighter distortion tolerances in the display, delete the sentence following (4). Otherwise define the applicable area(s) in blank (4a) (e.g., "covered by the HUD") and place the applicable tolerance value in blank (4b). (In past applications, the tolerable distortion in the area of the HUD was not permitted to exceed 0.5 percent of picture height.)

Verification Guidance:

EXECUTION AND EVALUATION GUIDANCE NOTES:

The number of dots in the test pattern need not be excessive since closely spaced dots are difficult to identify during test and do not alter the test results. Usually about ten measurements suffice to assure compliance. Dot positions should be measured near the center, the edge, and the corners of the field of view. Other dot positions should be measured as necessary.

EXAMPLES
A display for a cockpit that includes a HUD.

3.7.2.1.8 Geometric Distortion. The geometric distortion in each display channel shall not be greater than two percent of the picture height within a circle of diameter equal to the picture height, and shall not be greater than three percent of the picture height outside a circle of diameter equal to the picture height. Displays shall be aligned such that the maximum distortion anywhere within the field of view shall not be greater than four percent of the picture height. Geometric distortion in the area covered by the HUD shall not be greater than 0.5 percent of the picture height.

3.7.2.1.9 Collimation Quality. (1)The image presented to the nominal eyepoint shall be displayed at __2__. Collimation errors, as measured within the exit pupil, shall not be greater than __3__ diopters divergent from the display or __4__ diopters convergent from the display. Dipvergence shall not be greater than __5__ milliradians.

4.2.1.7.2.1.9 Verification of Collimation Quality. (6)This requirement shall be verified by test. A test pattern consisting of a minimum of ten rows by ten columns of equal-angularly spaced dots shall be used. Measurements shall be made using a standard parallel telescope consisting of two parallel collimated and calibrated monoculars separated by an interocular distance of 70 mm; one of the monoculars shall have a reticle calibrated in diopters. Collimation shall be measured with the telescope placed at the design eyepoint. A sufficient number of dots shall be measured to ensure compliance throughout the field of view. Lateral deviations observed through the parallel telescope shall represent convergence and dipvergence errors. Vertical deviations represent dipvergence.

RATIONALE
Collimation quality is a measure of the apparent range of the displayed image in a collimated display. A perfectly collimated display would present the scene at infinity. It is, however, impossible to achieve perfect collimation. Poor collimation can result in pilot fatigue, headaches, or nausea. It is important to control collimation quality in order to avoid these effects.

Definitions for collimation are often confused because different literature presents the information from different points of view. The definitions used herein are stated in terms of the direction in which the light rays go.

Collimation tests sometimes reveal optical misalignments that might otherwise go unnoticed, and unnecessarily lead to simulator-induced pilot fatigue, headaches, or nausea. For example, if the top of the display is found to be primarily convergent and the bottom primarily divergent, it may be possible to readjust the CRT or optics to equalize the collimation errors. In such cases, trade-offs should emphasize minimizing convergence errors since these are less tolerable than dipvergence errors.

Commercial regulatory standards do not explicitly specify a tolerance or measure collimation, but instead rely on an unwritten understanding that display quality must be reasonable if the simulator is to be qualified.

Requirements Guidance:

1. This requirement applies only to collimated displays. If there are none, either delete this requirement entirely or replace the paragraph following (1) with "This requirement is not applicable." Otherwise, continue to tailor in accordance with the following.

2. In blank (2), insert the distance at which the display is to be collimated. Normally, the ideal condition is to have the display collimated at or near infinity. A HUD display presents special problems for collimation. Unfortunately, HUDs are factory aligned and typically collimated to distances of 200 to 300 feet (61 to 91 meters). If the display were collimated at infinity and the HUD at 200 feet, the target would appear to move with respect to the HUD reticle as the pilot's head moved. Since HUDs are prealigned, it is often easier in practice to collimate the display to the same distance as the HUD in the area observed through the HUD.

3. In blank (3), insert the tolerance limit for divergent rays. An object that appears closer than infinity has rays that diverge toward the observer. The dipvergence is expressed in diopters as D=1/f, where f is the focal length in meters. In a perfectly collimated display, the object would appear in front of the viewer at infinity, with a collimation of 0.0 diopters. The eye can accommodate displays that are divergent because divergent rays occur in a natural real scene, and the eye muscles can focus on the image without strain. A typical dipvergence display requirement is -0.1 diopters.

4. In blank (4), insert the tolerance limit for convergent rays. Optical systems can create rays converging toward the observer. Converging rays do not occur in nature. These rays intersect behind the observer and are expressed as a positive diopter. +0.02 diopter convergent rays indicate an object with a focal distance 50 meters behind the observer. The eye cannot tolerate convergent rays, so alignment trade-offs should minimize convergent rays at the expense of divergent rays. A display convergence of +0.02 diopters usually is acceptable.

5. In blank (5), insert the tolerance limit for dipvergence. Dipvergence is measured in milliradians and represents a difference in apparent elevation angle between the rays entering each eye. Dipvergence does not occur naturally and only a small amount can be tolerated by the eye. A typical display specification is 5 milliradians.

Verification Guidance:

6. This requirement applies only to collimated displays. If there are none, either delete this requirement entirely or replace the paragraph following (6) with "Verification of this requirement is not applicable."

EXECUTION AND EVALUATION GUIDANCE NOTES:
Alignment of any parallel telescope should be verified prior to use by measuring the collimation of a distant real object. Minor miscalibration of the telescope can significantly affect the measurement.

Collimation varies through the display, so it must be measured at various points. Collimation should be measured in the center and near the corners of the display. Additional measurements should also be made near the edges and at random positions throughout the field of view. Ten points are usually sufficient to verify the requirement.

Note that foreign simulator vendors often use parallel telescopes with an interocular spacing of 67 mm rather than 70 mm. Although this introduces some measurement error, it is insignificant for practical purposes.

3.7.2.1.10 Swimming. Objectionable swimming of the visual image shall not be observable as an observer's eyepoint is moved within the display's exit pupil.

4.2.1.7.2.1.10 Verification of Swimming. This requirement shall be verified by analysis and inspection. The exit pupil of each display shall be substantiated by analysis. Inspection shall be conducted by an observer moving his or her eyes through each exit pupil from various directions, using side-to side, top-to-bottom, and bottom-to-top head motions.

RATIONALE

Commercial regulatory standards do not explicitly address swimming, but instead rely on an unwritten understanding that display quality must be reasonable if the simulator is to be qualified.

Requirements Guidance: *Swimming occurs in a visual display system when small optical errors cause the images to appear to wave as the observer moves his or her head.*

Verification Guidance:

EXECUTION AND EVALUATION GUIDANCE NOTES:
Any display system using optical elements is subject to some swimming. Should any swimming be observed within the exit pupil, judgment must be exercised regarding whether it is objectionable. There is no good way to quantify what constitutes an objectionable amount of swimming.

3.7.2.1.11 Display Refresh and Update Rates. The display of the visual imagery shall be refreshed at rates sufficiently high to ensure constant brightness and a flicker-free presentation, (1)except that some flicker may be observed for brightly lit objects (e.g., those illuminated by landing lights) in dusk/night imagery. (2)The display shall be updated in a manner that prevents occurrences of the field tracking phenomenon. (3)Under normal (i.e., non-overloaded) conditions, the visual imagery shall be updated at rates that prevent the apparent multiplication of dynamic elements in the image.

4.2.1.7.2.1.11 Verification of Display Refresh and Update Rates. This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that display refresh and update rates are consistent with the requirement. Demonstration conducted in conjunction with visual system verification shall verify that flicker conforms to the requirement.

RATIONALE
Display refresh and update rates are fundamental parameters affecting the quality of the displayed imagery. While display refresh rates must assure that eye strain and fatigue with prolonged viewing will be avoided, other artifacts associated with refresh and update rates may be unacceptably distracting or provide inappropriate cuing for specific applications.

Commercial regulatory standards do not explicitly specify display refresh or update rates, but instead rely on an unwritten understanding that display quality must be reasonable if the simulator is to be qualified.

Requirements Guidance:

1. If both night and dusk OTW imageries are not required of the visual system, tailor "dusk/night" in the phrase following (1) to be consistent with the requirement. The intent of the phrase following (1) is to allow some flicker of brightly lit objects in dusk/night scenes so that the refresh rate can be lowered for dusk/night illumination levels in order to permit a greater number of light points to be drawn; this is acceptable in commercial flight simulators. If it is expected that simulated operations will often include dusk/night scenes where luminous polygons cover a significant portion of the display -- or if there are other scenarios that would cause flicker problems with lower rates, delete the phrase "except that some flicker may be observed for brightly-lit objects (e.g., those illuminated by landing lights) in dusk/night imagery" following (1).

2. Field tracking is not beautiful, but interlaced displays are typically employed in both commercial and military simulator applications. Field tracking is a phenomenon that is often acceded to as a tradeoff for other performance or cost benefits. Delete the sentence following (2) unless field tracking is a concern for the specific application.

3. If the update rate of a displayed image is slower than the refresh rate, objectionable perceptual artifacts can be introduced as elements of the scene move across the scene. First, if the resultant update rate is too low, stepping will occur -- particularly when the eyepoint is moving or rotating rapidly.

Secondly, the images of rapidly moving objects in the scene will appear to multiply, with the number of apparent images depending on how many times the image is refreshed between updates.

The perceived multiplication of points and edges has two potential consequences. The less serious is that the apparent multiple images may be distracting and reduce the display's realism. The more serious consequence is that the perceived separation of the multiple points or edges is a potential cue to velocity that does not exist in direct vision. The true seriousness of this problem for training or mission rehearsal in a simulator has never been studied, and is not known. The importance of updating the image at the field rate must be decided for the specific application. Unless an analysis of system requirements and tradeoffs determines that the cost of updating the image at the field rate is justified, delete the sentence following (3).

Verification Guidance: *An analysis of the refresh and update rates used in the visual system should be adequate to substantiate compliance with the requirement since, except for flicker, the steps to achieve the required performance are discrete. If refresh rates are borderline, demonstrations in conjunction with other test procedures, such as verifying airport scene content will suffice to ascertain whether flicker is acceptable or not.*

NOTE REGARDING REFRESH RATES AND FLICKER
Display refresh rates need to be high enough to avoid perceptible flicker and eye strain. In a visual display, sequenced frames are displayed one at a time, in order, and at a fixed rate. Typically 30 to 60 frames/sec are displayed. The frames are often divided into two fields (one of even lines and one of odd lines) that are displayed sequentially (i.e., interlaced) in order to double the effective refresh rate without a concomitant increase in bandwidth. The intent of this procedure is to avoid flicker perception and eye strain.

With an effective refresh rate of 50 to 60 refreshes/sec and typical daylight-scene illumination levels, constant brightness and a flicker-free presentation are achieved. Typically, for raster display systems with standard CRT phosphors, an effective refresh rate of 60 refreshes/sec is achieved using 30 frames/sec with a 2:1 interlace. A dim picture or a high-persistence phosphor may be acceptable with a lower refresh rate. Hence, a refresh rate of 30 refreshes/sec is sufficient to avoid noticeable flicker for dusk/night scenes (excepting that objects represented by luminous polygons, i.e., polygons displayed at full day-mode intensity, may cause flicker if they cover too large a portion of the display).

NOTE REGARDING INTERLACE AND FIELD TRACKING
A frame divided into a sequence of fields (i.e., interlaced) is acceptable for most applications. However, when a frame is interlaced the display of alternate rasters causes problems with visual perception that might be unacceptable in certain applications. These problems arise because of the changes occurring on the frame in a local area of alternating rasters about the receptive fields of retinal receptors. When the eye locks onto an object that is moving roughly perpendicular to the raster structure at a rate that causes it to move a distance coinciding with the distance between raster lines in a single field, the two raster fields are seen by the eye as overlaying each other. The subjective effect is that there are half the number of raster lines creating the image, with all the apparent aliasing effects one would expect in that situation. The effect is further compounded by aliasing effects due to temporal changes in the image. Features will change shape or even disappear under some dynamic conditions. During slow, constant-rate pitch maneuvers (or yaw maneuvers in a vertical-raster system) the entire scene may be subject to this effect. This is the phenomenon known as "field tracking". It is a phenomenon present in all interlaced displays, and little can be done in the image generator to overcome it.

NOTE REGARDING REFRESH RATES, UPDATE RATES, AND APPARENT IMAGE MULTIPLICATION
It is not unusual to design the visual system to refresh the same image two (or more) times before the image generator updates a new picture. This gives the image generator twice as long (or longer) to calculate the new scene. Many systems operate in this way, either as their normal mode or as a function of overload. This is sometimes called running at frame rate as opposed to field rate.

If the update rate of a displayed image is slower than the refresh rate, elements of the scene may appear to multiply as they move across the scene. To understand how moving elements appear to multiply, consider the following example. Consider the situation with 2:1 interlace where the imagery is updated 30 times per second while an odd or even field is refreshed every 1/60 of a second. A dot moving across a display should appear at a new position at every refresh, whether of the odd or even field. If the display is not updated at every refresh, however, the dot will be frozen in position for each frame (appearing once in that position in the odd field and again in the same position in the even field). This representation is not consistent with the smooth motion of a single dot in direct vision. It results in the perception of two dots, separated in space by the amount of motion that should have taken place between the odd and even refresh times -- although only one dot is intended in the display. (Note that the same effect occurs in non-interlaced displays and motion pictures. A rapidly moving dot appears to double or triple, depending on whether a projector displays each frame two or three times before moving to a new frame.)

One method for mitigating this anomaly for rotation about the eyepoint is to calculate a slightly larger image than is being displayed. When the eyepoint rotates, the image is slid in the same direction so that the next display includes "new" pixels that were not in the original. When an update occurs, the display window is returned to the center of the calculated image; the image is then slid for each subsequent refresh until the next update -- at which point the process is repeated. This technique causes a slight reduction in image resolution because some portion of the image is not displayed. The size of the buffer area around the edges of the displayed image will depend on the maximum expected rotational rates of the eyepoint. This technique will not work for rapid eyepoint translation because new image geometry is required as the eyepoint's position changes relative to features in the database.

Process Guidance: *Since image generator capacity and scene content interact with refresh and update rates in ways other than the performance parameters cited in this paragraph, there is no general best set of overall performance requirements for all applications -- nor is it generally possible to intelligently determine the optimal set of requirements early in the development process. These requirements need to be optimized for the specific application through cost/performance tradeoffs that are part of the process of defining the design solution. If both a system specification and PIDS are used on a program, then this paragraph need not be included in the system specification. If only one specification is used for the device, then it may be necessary to make this requirement "TBD" and define a statement of work process to rewrite it later. If both specifications are used, the statement of work should task development of the applicable PIDS requirement.*

EXAMPLES
Example 1. A requirement for a visual system display that is consistent with commercial regulatory expectations for a Level D flight simulator.

3.7.2.1.11 Display Refresh and Update Rates. The display of the visual imagery shall be refreshed at rates sufficiently high to ensure constant brightness and a flicker-free presentation, except that some flicker may be observed for brightly lit objects (e.g., those illuminated by landing lights) in dusk/night imagery.

Example 2. A requirement for a simulator that is to be used to rehearse missions predominately occurring at night. Brightly illuminated objects will often occupy a large portion of the field of view. Crewmember eyestrain and other symptoms that may result from observing a display with excessive flicker for a prolonged period of time are a concern. It is also important that light patterns and other mission-significant fixtures that the crewmembers observe during rehearsals in the simulator unambiguously match those of the real world; hence image multiplication is a concern -- as are the effects of field-tracking.

3.7.2.1.11 Display Refresh and Update Rates. The display of the visual imagery shall be refreshed at rates sufficiently high to ensure constant brightness and a flicker-free presentation. The display shall be updated in a manner that prevents occurrences of the field tracking phenomenon. Under normal (i.e.,

non-overloaded) conditions, the visual imagery shall be updated at rates that prevent the apparent multiplication of dynamic elements in the image.

3.7.2.1.12 Night Vision Goggle Simulation. Imagery shall be simulated for the __1__ Night Vision Goggle (NVG) system in accordance with the approved design criteria. (2)The effects of __2a__ shall be simulated. (3)An optical line pair (OLP) subtending a visual angle of __3a__ arc-minutes shall be resolvable anywhere within the NVG field of view. (4)The dynamic luminance range shall extend from not greater than __4a__ footlamberts to not less than __4b__ footlamberts. (5)Low-light level intensity resolution shall not be greater than __5a__ footlamberts over the luminance range from __5b__ to __5c__ footlamberts.

4.2.1.7.2.1.12 Verification of Night Vision Goggle Simulation. This requirement shall be verified by analysis, (6) demonstration and test. (7)A test pattern in the database that is processed in the identical way as the operational database shall be used to demonstrate the required resolution. Analysis shall verify that the test pattern and viewing distances used in the demonstration result in the subtense of visual angles corresponding to the required resolution. Demonstration shall verify that the required NVG effects are simulated. (8)Test, conducted in conjunction with the "Verification of Brightness", shall verify dynamic luminance range and low-light level resolution.

RATIONALE
Night Vision Goggles (NVGs) are being used on an ever-increasing number of military aircraft. If the aircraft to be simulated for this application does not currently utilize NVG capability, it should be determined whether NVGs may be used in the near future. If NVG simulation will be needed, it is best to include the necessary capability in the original device. This will avoid costly rework -- or even swap-outs -- of visual system components necessary to incorporate NVG simulation. If no NVG simulation requirement is foreseen, delete this paragraph.

Commercial aviation regulatory standards do not address NVG simulation.

Requirements Guidance:

1. In blank (1), identify the NVG system to be simulated.

2. If only enumerated NVG effects are required in the simulation, retain the sentence following (2). Enumerate the required simulation effects in blank (2a). Typically these might include effects of moonlight, illumination levels, moon angle, starlight, ground lights, aircraft lights, and varying cloud conditions. Only specify needed effects. Over-specifying requirements here can increase costs or have a negative effect on other capabilities. If the simulated effects are not to be limited to a specified set, delete the sentence following (2).

3. The resolution should be consistent with the design criteria. If so, the sentence following (3) may be redundant to the first sentence and should probably be deleted in a system specification. The sentence following (3) should be included in the PIDS, however, to assure no misunderstandings regarding the delivered capability. When this sentence is retained, specify the resolution required within the NVG's field of view in blank (3a). Typically NVGs require that an optical line pair subtending six to eight arc-minutes be resolvable.

4. The sentence following (4) should normally be deleted in system-level specifications since this requirement hinges upon a particular design solution. At the PIDS level, this sentence should be retained if it is appropriate to the design solution. If the NVG simulation is to utilize a helmet-mounted display (HMD) approach, the sentence following (4) can be deleted and specifics regarding the HMD approach should be included under paragraph 3.7.3.6.3.3 "Night Vision Systems/Helmet Mounted Displays" (under the "Simulated Air Vehicle System" section). Otherwise, retain the sentence following (4), and specify the dynamic luminance range required in blanks (4a) and (4b). This is usually the luminance range of the

actual NVGs used in the aircraft. Approximate values would be 0.00005 footlamberts in blank (4a) and 5.0 footlamberts in blank (4b); the actual values should be derived from the design criteria.

5. The sentence following (5) should normally be deleted in system-level specifications since this requirement hinges upon a particular design solution. At the PIDS level, this sentence should be retained if it is appropriate to the design solution. If the NVG simulation is to utilize a helmet-mounted display (HMD) approach, the sentence following (5) can be deleted and specifics regarding the HMD approach should be included under paragraph 3.7.3.6.3.3 "Night Vision Systems/Helmet Mounted Displays" (under the "Simulated Air Vehicle System" section). Otherwise, retain the sentence following (5), and specify the appropriate values in blanks (5a), (5b), and (5c). In blank (5a), specify the largest value for the low-light level intensity resolution that is acceptable; values for low-light level intensity resolution are typically in the neighborhood of 0.00005 footlamberts. In blanks (5b) and (5c), specify the range over which the intensity resolution specified in blank (5a) applies. Normally this is only a small, lower portion of the overall dynamic range defined in blanks (4a) and (4b). Representative values for the range over which the intensity resolution would apply are from 0.00005 footlamberts to 0.1 footlamberts. Actual values used should be derived from the design criteria.

Verification Guidance:

6. Tailor the phrase "demonstration and test" following (6) to be consistent with the tailored verification requirement (e.g., see (8) below).

7. For computer-generated image systems, verification should be accomplished with a test pattern in the database that is processed in the identical way as the operational environment database. For camera-model or pure optical systems, the sentence following (7) should be replaced with, "A resolution test chart shall be substituted for the model."

8. If sentences (4) and (5) were deleted from the requirement (i.e., if the OTW display system is not being used for the NVG simulation), delete the sentence following (8) and the reference to "test" following (6).

EXAMPLES
Example 1. A system specification requirement for Night Vision Goggle (NVG) simulation. The performance capabilities are well documented in the design criteria.

3.7.2.1.12 Night Vision Goggle Simulation. Imagery shall be simulated for the model ANVIS-6 Night Vision Goggle (NVG) system in accordance with the approved design criteria. The effects of moonlight, illumination levels, moon angle, starlight, ground lights, aircraft lights, and varying cloud conditions shall be simulated.

4.2.1.7.2.1.12 Verification of Night Vision Goggle Simulation. This requirement shall be verified in accordance with the procedures defined in the PIDS.

Example 2. A PIDS requirement for Night Vision Goggle (NVG) simulation. The design solution selected by the contractor is to use the OTW display system to display the NVG imagery.

3.7.2.1.12 Night Vision Goggle Simulation. Imagery shall be simulated for the model ANVIS-6 Night Vision Goggle (NVG) system in accordance with the approved design criteria. The effects of moonlight, illumination levels, moon angle, starlight, ground lights, aircraft lights, and varying cloud conditions shall be simulated. An optical line pair (OLP) subtending a visual angle of eight arc-minutes shall be resolvable anywhere within the NVG field of view. The dynamic luminance range shall extend from not greater than 0.00005 footlamberts to not less than 5.0 footlamberts. Low-light level intensity resolution shall not be greater than 0.00005 footlamberts over the luminance range from 0.00005 to 0.1 footlamberts.

4.2.1.7.2.1.12 Verification of Night Vision Goggle Simulation. This requirement shall be verified by analysis, demonstration and test. A test pattern in the database that is processed in the identical way as the operational database shall be used to demonstrate the required resolution. Analysis shall verify that the test pattern and viewing distances used in the demonstration result in the subtense of visual angles corresponding to the required resolution. Demonstration shall verify that the required NVG effects are simulated. Test, conducted in conjunction with the "Verification of Brightness", shall verify dynamic luminance range and low-light level resolution.

Example 3. A PIDS requirement for Night Vision Goggle (NVG) simulation. The design solution selected by the contractor is to use a helmet-mounted display approach, where simulated NVGs incorporating a built-in visual display system will be provided for each of the required crewmembers. This ties into the example provided for paragraph 3.7.3.6.3.3 "Night Vision Systems/Helmet Mounted Displays", which is under the "Simulated Air Vehicle" section of this guide specification.

3.7.2.1.12 Night Vision Goggle Simulation. Imagery shall be simulated for the model ANVIS-6 Night Vision Goggle (NVG) system in accordance with the approved design criteria. The effects of moonlight, illumination levels, moon angle, starlight, ground lights, aircraft lights, and varying cloud conditions shall be simulated. An optical line pair (OLP) subtending a visual angle of eight arc-minutes shall be resolvable anywhere within the NVG field of view.

4.2.1.7.2.1.12 Verification of Night Vision Goggle Simulation. This requirement shall be verified by analysis and demonstration. A test pattern in the database that is processed in the identical way as the operational database shall be used to demonstrate the required resolution. Analysis shall verify that the test pattern and viewing distances used in the demonstration result in the subtense of visual angles corresponding to the required resolution. Demonstration shall verify that the required NVG effects are simulated.

3.7.2.3 Physical Motion Cuing.

4.2.1.7.2.3 Verification of Physical Motion Cuing. CHOOSE ONE OF THE TWO FOLLOWING SENTENCES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by ____1____.

GUIDANCE TO AUTHOR:
Select one of the two above sentences for the VERIFICATION paragraph. If the second sentence applies, fill in blank (1) with "inspection", "analysis", "demonstration", or "test". Treat the second sentence as a paragraph lead-in, then provide details regarding the particular verification method.
THEN DELETE THIS GUIDANCE TO AUTHOR.

RATIONALE

Requirements Guidance:

Verification Guidance:

Process Guidance:

3.7.2.3.1 Motion Platform.

4.2.1.7.2.3.1 Verification of Motion Platform. CHOOSE ONE OF THE TWO FOLLOWING SENTENCES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by ____1____.

GUIDANCE TO AUTHOR:
Select one of the two above sentences for the VERIFICATION paragraph. If the second sentence applies, fill in blank (1) with "inspection", "analysis", "demonstration", or "test". Treat the second sentence as a paragraph lead-in, then provide details regarding the particular verification method.
THEN DELETE THIS GUIDANCE TO AUTHOR.

RATIONALE

Requirements Guidance:

Verification Guidance:

Process Guidance:

3.7.2.3.2 Within-cab Cuing Devices.

4.2.1.7.2.3.2 Verification of Within-cab Cuing Devices. CHOOSE ONE OF THE TWO FOLLOWING SENTENCES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by ____1____.

GUIDANCE TO AUTHOR:
Select one of the two above sentences for the VERIFICATION paragraph. If the second sentence applies, fill in blank (1) with "inspection", "analysis", "demonstration", or "test". Treat the second sentence as a paragraph lead-in, then provide details regarding the particular verification method.
THEN DELETE THIS GUIDANCE TO AUTHOR.

RATIONALE

Requirements Guidance:

Verification Guidance:

Process Guidance:

3.7.2.3.2.1 Dynamic Seat.

4.2.1.7.2.3.2.1 Verification of Dynamic Seat. CHOOSE ONE OF THE TWO FOLLOWING SENTENCES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by ____1____.

GUIDANCE TO AUTHOR:
Select one of the two above sentences for the VERIFICATION paragraph. If the second sentence applies, fill in blank (1) with "inspection", "analysis", "demonstration", or "test". Treat the second sentence as a paragraph lead-in, then provide details regarding the particular verification method.
THEN DELETE THIS GUIDANCE TO AUTHOR.

RATIONALE

Requirements Guidance:

Verification Guidance:

Process Guidance:

3.7.2.3.2.2 Vibration Cuing.

4.2.1.7.2.3.2.2 Verification of Vibration Cuing. CHOOSE ONE OF THE TWO FOLLOWING SENTENCES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by ____1____.

GUIDANCE TO AUTHOR:
Select one of the two above sentences for the VERIFICATION paragraph. If the second sentence applies, fill in blank (1) with "inspection", "analysis", "demonstration", or "test". Treat the second sentence as a paragraph lead-in, then provide details regarding the particular verification method.
THEN DELETE THIS GUIDANCE TO AUTHOR.

RATIONALE

Requirements Guidance:

Verification Guidance:

Process Guidance:

3.7.2.3.2.3 Anti-G Suit Pressure.

4.2.1.7.2.3.2.3 Verification of Anti-G Suit Pressure. CHOOSE ONE OF THE TWO FOLLOWING SENTENCES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by ____1____.

GUIDANCE TO AUTHOR:
Select one of the two above sentences for the VERIFICATION paragraph. If the second sentence applies, fill in blank (1) with "inspection", "analysis", "demonstration", or "test". Treat the second sentence as a paragraph lead-in, then provide details regarding the particular verification method.
THEN DELETE THIS GUIDANCE TO AUTHOR.

RATIONALE

Requirements Guidance:

Verification Guidance:

Process Guidance:

3.7.2.3.2.4 Musculoskeletal Loading.

4.2.1.7.2.3.2.4 Verification of Musculoskeletal Loading. CHOOSE ONE OF THE TWO FOLLOWING SENTENCES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by ____1____.

GUIDANCE TO AUTHOR:
Select one of the two above sentences for the VERIFICATION paragraph. If the second sentence applies, fill in blank (1) with "inspection", "analysis", "demonstration", or "test". Treat the second sentence as a paragraph lead-in, then provide details regarding the particular verification method.
THEN DELETE THIS GUIDANCE TO AUTHOR.

RATIONALE

Requirements Guidance:

Verification Guidance:

Process Guidance:

3.7.2.4 Aural Cuing. Significant cockpit sounds which result from (1) pilot action, precipitation, windshield wipers, other significant noises during operations, and the sound of crash shall be simulated. (2)In addition, the power spectra of these sounds shall match the power spectra of recorded aircraft

sounds, and the sounds shall be coordinated with the out-the-window visual representations of weather required by this specification. (3)Sound simulation shall also include the following: (4)

EQUIPMENT SOUNDS
Ground Cart
Auxiliary Power Unit (APU)
Equipment Cooling Fan
Gasper Fan
Air Conditioning
Auto Speedbrake
Nose Gear Lock
Nose Wheel Release Hiss
Nose Wheel Spindown
Standby Hydraulic Pump
__5__

ENGINE SOUNDS
Compressor Whines
Air Intake Sound
Efflux Roar
Compressor Stall
__5__

SLIPSTREAM AND RUNWAY SOUNDS
Flight Deck Aero Sounds
Nose Gear Aero
Wheel Well Resonance
Flap Buffet
Spoiler Buffet
Stall Buffet
Main Gear Taxi Rumble
Nose Gear Taxi Rumble
Main Gear Touchdown
Nose Gear Touchdown
Explosive Decompression
__5__

ENVIRONMENTAL SOUNDS
Rain/Hail
Thunder
__5__

4.2.1.7.2.4 Verification of Aural Cuing. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES

This requirement shall be verified by demonstration (6) and test. Aural cuing shall be verified in accordance with the procedures of Section 5 "Sound System" of the "Airplane Flight Simulator Evaluation Handbook" for a Level __7__ simulator, except that the list of simulated sounds shall comply with the requirements of this specification.

-OR-

This requirement shall be verified by demonstration (8) and test. Aural simulation shall be verified in accordance with (8) Appendix 2 and Appendix 3 of AC-120-63.

RATIONALE

Aural cues can cause significant modifications of control behavior. Aircrew members are very attuned to the sounds around them -- especially engine sounds. Abnormal sounds, or the omission of normal sounds, provide alerting cues regarding potential problems. Aural cuing will normally be required for training, but should not be included automatically; for example, aural cuing may not be appropriate in small, open-cockpit, unit-level trainers.

Requirements Guidance:

1. All levels of airplane and helicopter simulators require the simulation of "significant cockpit sounds which result from pilot action". Level C and D airplane and helicopter simulators additionally require the simulation of the sounds of "precipitation, windshield wipers, other significant noises during operations, and the sound of crash". Tailor the phrase following (1) to be consistent with the requirement.

2. If this is to be a Level D airplane or helicopter simulator, retain the sentence following (2). Otherwise, delete the sentence following (2).

Level D airplane and helicopter simulators require that the amplitude and frequency of the simulated sounds be realistic (i.e., the power spectra of recorded aircraft sounds must be matched), and that the sounds be coordinated with out-the-window visual representations of weather.

3. Delete all text following (3) in a System-level specification. For a PIDS, continue with steps 4 and 5.

4. Tailor the list following (4). This list is reproduced from Section 5 "Sound System" of the "Airplane Flight Simulator Evaluation Handbook". It contains the sounds normally simulated in commercial airplane simulators, but may not be appropriate for all military applications (e.g., if the simulation will not include ground operations, a number of the list entries may be deleted). The list also is not entirely appropriate for helicopter simulators, e.g., Appendix 3 of AC-120-63 identifies engine, rotor, transmission, landing gear, and other airframe sounds as significant helicopter noises.

5. Add military-unique sound simulation requirements in blanks (5). For example, sounds such as canopy jettison, ejection seat activation, external stores release/jettison, and weapon firing might be included under Equipment Sounds.

Verification Guidance: *Select the alternative that is consistent with the requirement. The first alternative is for an airplane simulator. The second alternative is for a helicopter simulator.*

6. If the airplane simulator is to be consistent with Level D, retain the phrase "and test". Otherwise delete "and test".

Lower-level verification procedures in the "Airplane Flight Simulator Evaluation Handbook" are subjective. For Level D simulators, objective test measurements are made to compare the power spectra of the simulated sounds to their counterparts recorded in the aircraft.

7. Insert the Level of the airplane simulator in blank (7), consistent with the requirement.

Using the "Airplane Flight Simulator Evaluation Handbook" test procedures will provide consistency with commercial practice. Since that document lists the sounds that "should be included", a tailored list should appear in the PIDS to clarify the actual requirement (see Requirements Guidance for 4, above).

8. If the requirement is consistent with that for a Level D helicopter simulator, retain the phrases "and test" and "Appendix 2 and". Otherwise delete the phrases "and test" and "Appendix 2 and".

For Level D helicopter simulators, Appendix 2 of AC-120-63 requires objective test measurements to compare the power spectra of the simulated sounds to their counterparts recorded in the aircraft. Appendix 3 requires only subjective evaluation.

Process Guidance: *It may be necessary or desirable to let the contractor complete blanks (4) and (5) as part of a source selection or in accordance with a Statement of Work task with appropriate requirements for update at PDR and CDR.*

EXAMPLES
Example 1. The System Specification requirement for a part-task trainer intended for procedural refresher training of mission-qualified pilots. The emphasis is on in-flight emergencies and the use of avionics equipment in air-to-air and air-to-ground modes. There is no requirement for training below 200 feet AGL. A Training System Requirements Analysis has determined that a Level C simulator is adequate, and that aural cuing is required.

3.7.2.5 Aural Cuing. Significant cockpit sounds which result from pilot action, precipitation, windshield wipers, other significant noises during operations, and the sound of crash shall be simulated.

Example 2. The PIDS requirement for the above part-task trainer.

3.7.2.5 Aural Cuing. Significant cockpit sounds which result from pilot action, precipitation, windshield wipers, other significant noises during operations, and the sound of crash shall be simulated. Sound simulation shall also include the following:

EQUIPMENT SOUNDS
- Auxiliary Power Unit (APU)
- Equipment Cooling Fan
- Exhaust Fan
- Air Conditioning
- Speedbrake
- Windscreen Wiper
- Standby Hydraulic Pump
- Canopy Jettison
- Ejection Seat Activation
- External stores release/jettison
- Missile Launch

ENGINE SOUNDS
- Compressor Whines
- Air Intake Sound
- Efflux Roar
- Compressor Stall

SLIPSTREAM AND RUNWAY SOUNDS
- Flight Deck Aero Sounds
- Flap Buffet
- Spoiler Buffet
- Stall Buffet
- Explosive Decompression

ENVIRONMENTAL SOUNDS
- Rain/Hail
- Thunder
- Small Arms Fire Impact

3.7.3 Simulated Air Vehicle. The performance, flying qualities, control reactions, and air vehicle systems of the __1__ aircraft shall be simulated in accordance with the requirements of this section.

4.2.1.7.3 Verification of Simulated Air Vehicle. This requirement shall be verified by demonstration.

NOTE: This will include the FAA subjective tests, to be conducted after the objective tests in the subparagraphs are completed (this section is to be completed once the "subjective test" counterpart to the "Airplane Flight Simulator Evaluation Handbook" is available). This also will include the specific verification requirements of the subparagraphs.

RATIONALE
This section has been organized to parallel -- to the extent reasonable and practical -- the evolving "Air Vehicle Guide Specification". The organization of this section is summarized below.

a. Air Vehicle Dynamics. This subsection includes simulated air vehicle response and the flight control system functional requirements. No real correlate exists in the "Air Vehicle Guide Specification".

b. Air Vehicle Powerplant. This subsection includes the functional requirements for powerplant simulation. Again, no real correlate exists in the "Air Vehicle Guide Specification".

c. Air Vehicle Mission Management Systems. This subsection is intended to include functional requirements for simulation of relevant systems which fall under "Mission Management" of the "Air Vehicle Guide Specification".

d. Air Vehicle Utility Management Systems. This subsection is to include functional requirements for simulation of relevant systems falling under "Utility Management" of the "Air Vehicle Guide Specification".

e. Air Vehicle Health Management Systems. This is to include functional requirements for simulation of relevant "Integrated Diagnostics and Health Management" systems.

f. Air Vehicle Crew Systems. This includes requirements related to "Crew Systems" in the "Air Vehicle Guide Specification". In addition, the fidelity with which all crew station instruments, controls and displays are to be rendered is included in this subsection.

g. Weapons/Stores Simulation. This has no direct correlation with the "Air Vehicle Guide Specification". This section is intended to specify the stores to be simulated, their effect on the aircraft, and their interaction with aircraft systems until separation. Simulation requirements for stores after they have left the aircraft will be treated in the subparagraphs of the "Synthetic Environment" section of this document.

Requirements Guidance: *Specify the aircraft to be simulated in blank (1). This specification will define the airframe and specific air vehicle configuration to be simulated (e.g., "F-16A Block 15 Operational Capabilities Upgrade", "MC-130H Combat Talon II"). To further reduce ambiguity regarding configuration (particularly for operational aircraft which are subject to a number of field modifications), it may be advisable to also include the tail number of the specific aircraft to be simulated.*

Verification Guidance: *Commercially adopted standards should be applied wherever appropriate in order to provide consistency with commercial practice. These are embodied in the "International Standards for the Qualification of Airplane Flight Simulators" and its (in process) subjective test counterpart, and in the FAA Advisory Circular AC-120-63 "Helicopter Simulator Qualification".*

3.7.3.1 Air Vehicle Dynamics.

4.2.1.7.3.1 Verification of Air Vehicle Dynamics. Verification of this requirement is not applicable.

RATIONALE
This is a title-only, lead-in paragraph.

Requirements Guidance:

Any ground handling requirements are included under paragraph 3.7.3.1.1. Normal up-and-away flight performance and aerodynamic simulation requirements are included under paragraph 3.7.3.1.2. These

two paragraphs include standards imposed by the FAA on commercial aircraft simulators. Any military-specific requirements for simulation of post-stall departure, entry into spin, and subsequent recovery into controlled flight are included in paragraph 3.7.3.1.3.

Verification Guidance:

The test procedures in the "Airplane Flight Simulator Evaluation Handbook" provide a methodology for objective verification of compliance with Appendix 2 of the "International Standards for the Qualification of Airplane Flight Simulators" (which will be mirrored in FAA AC-120-40C for level C and D simulators). This handbook serves as the basic verification reference document in the following subparagraphs. This should be at hand -- and referred to -- while tailoring this guide specification.

No equivalent handbook document exists for helicopter simulators. For helicopter simulators, the appropriate tests from Appendix 2 of FAA Advisory Circular AC-120-63 "Helicopter Simulator Qualification" are referenced in the following subparagraphs. Again, this should be at hand -- and referred to -- while tailoring this guide specification.

The tolerances specified in the FAA AC-120-40C and the "Airplane Flight Simulator Evaluation Handbook" should be acceptable for transport-class aircraft, but probably will require some tailoring for high performance airplanes. Generally, commercial tolerances should be used unless there is good reason otherwise. Provisions are made for any necessary tolerance tailoring in the subparagraphs.

A quick reference to tolerance values typical of commercial and military airplane and helicopter simulators may be accessed by clicking on the 'light bulb' icon at the lower right on this page or the subparagraph pages in the hypertext ToolKit. DO NOT MAKE JUDGMENTS REGARDING THE SUITABILITY OF COMMERCIAL TOLERANCES BASED UPON A COMPARISON OF THE RAW NUMBERS. READ THROUGH THE RELEVANT COMMERCIAL TEST PROCEDURES AND STANDARDS IN ORDER TO UNDERSTAND THE CONTEXT BEFORE ARRIVING AT A CONCLUSION.

3.7.3.1.1 Ground Handling. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

Simulation of ground operations is not required.

-OR-

Ground effects, ground reaction (i.e., the reaction of the air vehicle upon contact with the landing surface), and ground handling characteristics shall be simulated in accordance with the approved design criteria. (1)The effects of reverse thrust on directional control shall be simulated. (2)In-ground-effect hover shall be simulated. (3)Stopping and directional control forces shall be simulated for landing surface conditions including: dry, wet, icy, patchy wet, patchy icy, and wet on rubber residue in the touchdown zone. (4)Brake and tire failure dynamics and decreased brake efficiency due to brake temperature shall be simulated.

4.2.1.7.3.1.1 Verification of Ground Handling. CHOOSE ONE OF THE FOLLOWING THREE ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test (5) demonstration, and analysis. Ground handling and operations simulation shall be verified by test in accordance with the procedures of the "Airplane Flight Simulator Evaluation Handbook" as follows: (6)

Section 1a Minimum radius of turn

Section 1a Nosewheel steering rate
Section 1b Ground acceleration
Section 1b Ground minimum control speed
Section 1b Minimum unstick speed
Section 1b Normal takeoff
Section 1b Critical engine failure on takeoff
Section 1b Crosswind takeoff
Section 1b Rejected takeoff
Section 1b Dynamic engine failure after takeoff
Section 1e Braking deceleration, dry runway
Section 1e Reverse thrust deceleration, dry runway
Section 1e Braking deceleration, wet runway
Section 1e Braking deceleration, icy runway
Section 2e Normal landing
Section 2e Minimum/no flap landing
Section 2e Crosswind landing
Section 2e One engine inoperative landing
Section 2e Autoland
Section 2e Go around, engine out
Section 2e Go around, all engines
Section 2e Rudder effectiveness with symmetric reverse thrust
Section 2e Rudder effectiveness with asymmetric reverse thrust
Section 2f Ground effect
Section 2g Brake fade

The tolerances in the "Airplane Flight Simulator Evaluation Handbook", (7) as amended by the following, shall apply.
__8__

(5)Analysis during design reviews shall verify that __9__. Simulation of __10__ shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3.

-OR-

This requirement shall be verified by test (5) demonstration, and analysis. Ground handling and operations simulation shall be verified by test in accordance with Appendix 2 of the AC-120-63 "Helicopter Simulator Qualification" as follows: (6)

Test 1b Minimum radius turn
Test 1b Rate of turn vs. pedal deflection or nosewheel angle
Test 1b Taxi
Test 1b Brake effectiveness
Test 1c Takeoff, all engines
Test 1c Takeoff, one engine inoperative
Test 1d Hover performance
Test 1e Vertical climb performance
Test 1j Landing, all engines
Test 1j Landing, one engine inoperative
Test 1j Balked landing
Test 1j Autorotational landing

The tolerances in Appendix 2 of the AC-120-63 "Helicopter Simulator Qualification", (7) as amended by the following, shall apply.
__8__

(5)Analysis during design reviews shall verify that __9__. Simulation of __10__ shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3.

RATIONALE

Full-fidelity simulation of ground operations is required for Level 1 and 2 airplane simulators and for Level B, C, and D helicopter simulators (except that hover simulation is not required for a Level B helicopter simulator).

Requirements Guidance: *Not all simulators necessarily have a requirement for ground operations (e.g., the purpose of the simulator may be to afford practice of air-to-air combat and air-to-ground weapon delivery only). If simulation of ground operations is not required, choose the first alternative. Select the second alternative to require full-fidelity simulation for ground operations.*

If the second alternative is selected:

1. Delete the sentence following (1) if the air vehicle being simulated does not have thrust reversers.

2. The sentence following (2) applies to Level C and D helicopter simulators only. Delete for other simulators.

3. Delete or otherwise tailor the sentence following (3) as necessary. This sentence, as written, reflects the requirement for Level 1 and 2 airplane simulators. Delete only the "wet on rubber residue in the touchdown zone" requirement for Level C and D helicopter simulators. Delete the whole sentence for Level B helicopter and other lesser-fidelity simulators.

4. The sentence following (4) applies to Level 1 and 2 airplane simulators and to Level C and D helicopter simulators. Delete this sentence for other lesser-fidelity simulators.

Verification Guidance: *Select the alternative consistent with the requirement. The second alternative is consistent with a Level 1 or 2 airplane simulator. The third alternative is consistent with a Level B, C, or D helicopter simulator (some further tailoring is required for Level B helicopter simulators).*

If the second or third alternative is selected:

5. Delete the phrase following (5) unless verification will include analysis, demonstration or both; if retained, tailor the phrase "demonstration, and analysis" as appropriate.

Also delete or tailor the two sentences following (5): "Analysis during design reviews shall verify that __9__. Simulation of __10__ shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3."

6. Tailor the list of tests following (6) to be consistent with the requirement.

For example, the following tests apply only to a Level C or D helicopter simulator:

Test 1d Hover performance
Test 1e Vertical climb performance
Test 1j Autorotational landing

7. If the tolerances that are included in the "Airplane Flight Simulator Evaluation Handbook" or "Helicopter Simulator Qualification" Advisory Circular are acceptable for the tests to be conducted, delete the phrase "as amended by the following" that follows (7). Otherwise retain this phrase.

8. If the phrase following (7) is retained, list the specific exceptions to the commercial tolerances using a tabular format.

9. Insert in blank (9) any requirements that are to be verified by analysis.

10. Insert in blank (10) any requirements that are to be verified by demonstration.

For Level 1 and 2 airplane simulators, include at least the following in blank (10): "stopping and directional control forces for landing surface conditions including: patchy wet, patchy icy, and wet on rubber residue in the touchdown zone".

For Level C and D helicopter simulators, include at least the following in blank (10): "stopping and directional control forces for landing surface conditions including: wet, icy, patchy wet, and patchy icy".

EXAMPLES
Requirements for a simulator for a single-engine fighter aircraft where a drogue parachute is deployed to slow the aircraft upon landing.

3.7.3.1.1 Ground Handling. Ground effects, ground reaction (i.e., the reaction of the air vehicle upon contact with the landing surface), and ground handling characteristics shall be simulated in accordance with the approved design criteria. Stopping and directional control forces shall be simulated for landing surface conditions including: dry, wet, icy, patchy wet, patchy icy, and wet on rubber residue in the touchdown zone. Brake and tire failure dynamics and decreased brake efficiency due to brake temperature shall be simulated.

4.2.1.7.3.1.1 Verification of Ground Handling. This requirement shall be verified by test and demonstration. Ground handling and operations simulation shall be verified by test in accordance with the procedures of the "Airplane Flight Simulator Evaluation Handbook" as follows:

Section 1a Minimum radius of turn; however, differential braking, with brake force set at the flight test value, shall be substituted for application of maximum tiller
Section 1a Nosewheel steering rate
Section 1b Ground acceleration
Section 1b Ground minimum control speed
Section 1b Minimum unstick speed
Section 1b Normal takeoff
Section 1b Crosswind takeoff
Section 1b Rejected takeoff
Section 1b Dynamic engine failure after takeoff
Section 1e Braking deceleration, dry runway
Section 1e Reverse thrust deceleration, dry runway; however, deployment of the drogue parachute shall be substituted for application of reverse thrust
Section 1e Braking deceleration, wet runway
Section 1e Braking deceleration, icy runway
Section 2e Normal landing
Section 2e Minimum/no flap landing
Section 2e Crosswind landing
Section 2e One engine inoperative landing (dead-stick landing)
Section 2e Go around, all engines
Section 2e Rudder effectiveness with symmetric reverse thrust; however, deployment of the drogue parachute shall be substituted for application of reverse thrust
Section 2f Ground effect
Section 2g Brake fade

The tolerances in the "Airplane Flight Simulator Evaluation Handbook", as amended by the following, shall apply.

Flight control forces

Longitudinal and lateral: 0.5 lb or 10%
Pedal: 2.0 lb or 10%

Calibrated airspeed
Specific reference values (e.g., minimum control speed): 2 knots
Otherwise the "Airplane Flight Simulator Evaluation Handbook" tolerance applies.

Simulation of stopping and directional control forces for landing surface conditions including: patchy wet, patchy icy, and wet on rubber residue in the touchdown zone shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3.

3.7.3.1.2 Flight Performance and Flying Qualities. The simulated air vehicle shall respond to flight and powerplant controls, and the synthetic environment in accordance with the requirements of this specification and the approved design criteria. The effect of aerodynamic changes for various combinations of drag and thrust encountered in flight shall be simulated; this shall include the effect of changes in air vehicle attitude, aerodynamic and propulsive forces and moments, altitude, temperature, gross weight, center of gravity location, (1) airframe icing, nonlinearities due to sideslip, and configuration (2) to include external load operations. (3)Aerodynamic interference effects between the rotor wake and fuselage and the influence of the rotor on control and stabilization systems shall be simulated. (4)Rotor aerodynamics shall simulate partial immersion in turbulent airwakes.

4.2.1.7.3.1.2 Verification of Flight Performance and Flying Qualities. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

This requirement shall be verified by test (5)demonstration, and analysis. Flight performance and flying qualities simulation shall be verified by test in accordance with the procedures of the "Airplane Flight Simulator Evaluation Handbook" as follows: (6)

Section 1c Normal climb, all engines operating
Section 1c Second segment climb, one engine inoperative
Section 1c Enroute climb, one engine inoperative
Section 1c Approach climb, one engine inoperative
Section 1c Level flight acceleration
Section 1c Level flight deceleration
Section 1d Cruise performance
Section 1f Engine acceleration on approach or landing
Section 1f Engine deceleration on the ground
Section 2b Small control inputs during cruise, yaw
Section 2b Small control inputs during cruise, pitch
Section 2b Small control inputs during cruise, roll
Section 2b Small control inputs on approach, yaw
Section 2b Small control inputs on approach, pitch
Section 2b Small control inputs on approach, roll
Section 2c Power change dynamics on approach
Section 2c Flap change dynamics during second to third segment climb, retraction
Section 2c Flap change dynamics on approach, extension
Section 2c Spoiler/speedbrake change dynamics during cruise, extension
Section 2c Spoiler/speedbrake change dynamics during cruise, retraction
Section 2c Gear change dynamics during first to second segment climb, retraction
Section 2c Gear change dynamics on approach, extension
Section 2c Gear operating times during takeoff, retraction
Section 2c Gear operating times on approach, extension
Section 2c Alternate gear operating times on approach, extension
Section 2c Flap operating times on the ground, retraction
Section 2c Flap operating times on approach, extension

Section 2c Alternate flap operating times on the ground, retraction
Section 2c Alternate flap operating times on approach, extension
Section 2c Longitudinal trim during cruise, approach, and landing
Section 2c Longitudinal maneuver stability during cruise, approach, and landing
Section 2c Longitudinal static stability on approach
Section 2c Stick shaker, buffet, and stall speeds during second segment climb and landing
Section 2c Phugoid dynamics during cruise
Section 2c Short period dynamics during cruise
Section 2d Minimum control speed during landing or takeoff (whichever is more critical)
Section 2d Roll response during cruise and landing (or approach)
Section 2d Step input of cockpit roll controller during landing (or approach)
Section 2d Spiral stability during cruise
Section 2d Engine inoperative trim during second segment climb and landing (or approach)
Section 2d Rudder response during landing (or approach)
Section 2d Dutch roll dynamics during cruise and landing (or approach)
Section 2d Steady state sideslip during landing (or approach)
Section 2i Overspeed envelope protection during cruise
Section 2i Minimum speed protection during takeoff, cruise, and approach (or landing)
Section 2i Load factor protection during takeoff and cruise
Section 2i Pitch angle protection during cruise and go-around
Section 2i Bank angle protection on approach
Section 2i Angle of attack protection during second segment climb and approach

The tolerances in the "Airplane Flight Simulator Evaluation Handbook", (7) as amended by the following, shall apply.
__8__

(5)Analysis during design reviews shall verify that __9__. Simulation of __10__ shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3.

-OR-

This requirement shall be verified by test (5) demonstration, and analysis. Flight performance and flying qualities simulation shall be verified by test in accordance with Appendix 2 of the AC-120-63 "Helicopter Simulator Qualification" as follows: (6)

Test 1f Level flight performance and trimmed flight control positions during cruise
Test 1g Climb performance and trimmed flight control positions, all engines operating
Test 1g Climb performance and trimmed flight control positions, one engine inoperative
Test 1h Descent performance and trimmed flight control positions
Test 1h Autorotation performance and trimmed flight control positions
Test 1i Autorotational entry from cruise or climb
Test 2b Low airspeed handling qualities, trimmed flight control positions, translation in ground effect
Test 2b Low airspeed handling qualities, critical azimuth, stationary hover
Test 2b Low airspeed handling qualities, longitudinal control response, step input, hover
Test 2b Low airspeed handling qualities, lateral control response, step input, hover
Test 2b Low airspeed handling qualities, directional control response, step input, hover
Test 2b Low airspeed handling qualities, vertical control response, step input, hover
Test 2c Longitudinal handling qualities, control response, step input, cruise
Test 2c Longitudinal handling qualities, static stability, step input, cruise and autorotation
Test 2c Longitudinal handling qualities, long term response, during cruise
Test 2c Longitudinal handling qualities, short term response, during cruise or climb
Test 2c Longitudinal handling qualities, maneuvering stability, during cruise or climb
Test 2c Landing gear operating time during takeoff, retraction
Test 2c Landing gear operating time on approach, extension

Test 2c Lateral & directional handling qualities, lateral control response, step input, cruise
Test 2c Lateral & directional handling qualities, directional control response, step input, cruise
Test 2c Lateral & directional handling qualities, directional static stability, cruise or climb and descent
Test 2c Lateral & directional handling qualities, dynamic lateral & directional stability, lateral-directional oscillations, cruise or climb
Test 2c Lateral & directional handling qualities, dynamic lateral & directional stability, spiral stability, cruise or climb
Test 2c Lateral & directional handling qualities, dynamic lateral & directional stability, adverse/proverse yaw, cruise or climb

The tolerances in Appendix 2 of the AC-120-63 "Helicopter Simulator Qualification", (7) as amended by the following, shall apply.
__8__

(5)Analysis during design reviews shall verify that __9__. Simulation of __10__ shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3.

RATIONALE

Requirements Guidance:

1. If the effects of airframe icing are not required, delete the phrase "airframe icing" following (1). Airframe icing effects are required for Level 1 and 2 airplane simulators, and ("if appropriate") for Level D helicopter simulators.

2. Delete the phrase "to include external load operations" following (2) if this is not a requirement.

3. The sentence following (3) is a requirement for Level D helicopter simulators only; delete for other simulators.

4. Delete the sentence following (4) unless there is a requirement for simulation of helicopter dynamics with the rotor partially submerged in turbulent airwakes (such as might be encountered in shipboard or aerial refueling operations). This is NOT a requirement of AC-120-63.

Verification Guidance: *Select the alternative consistent with the requirement. The first alternative is consistent with a Level 1 or 2 airplane simulator. The second alternative is consistent with a Level B, C, or D helicopter simulator (some further tailoring is required for Level B helicopter simulators).*

For the alternative selected:

5. Delete the phrase following (5) unless verification will include analysis, demonstration or both; if retained, tailor the phrase "demonstration, and analysis" as appropriate. At a minimum, this phrase should be retained if there is a requirement for simulation of helicopter dynamics with the rotor partially submerged in turbulent airwakes.

Also delete or tailor the two sentences following (5): "Analysis during design reviews shall verify that __9__. Simulation of __10__ shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3."

6. Tailor the list of tests following (6) to be consistent with the requirement.

If simulation of ground handling is not a requirement, modifications are required for those tests that would normally be conducted "on the ground" (e.g., these may instead require an altitude freeze to be commanded). In addition, there may be no need for certain tests. For example: (a) if landing gear need not be simulated, do not include tests for gear extension and retraction -- and assure that the landing

gear control is specified at the appropriate level of fidelity in paragraph 3.7.3.6.1.4 "Crew Station Panels", (b) if there is no requirement to simulate ground effects, do not include tests for hover or translation in ground effect.

Be certain to delete tests that make no sense. For example, a test for second segment climb with one engine inoperative would hardly apply to a single-engine aircraft.

Delete or modify tests to account for military-unique differences (e.g., use of afterburner and military power settings).

Delete or modify tests to account for selective fidelity -- make certain that all affected test procedures are identified. For example, if paragraph 3.7.3.4.7 "Landing Gear System" states that simulation of the landing gear system is not required, all tests regarding gear extension and retraction should be deleted. If paragraph 3.7.3.6.1.1 "Flight Controls" states that the flight control pedals shall be inert (note that paragraph 3.7.3.1.4 "Flight Control System" should then specify how the missing pedal control inputs are to be handled in the simulation), delete tests requiring rudder pedal inputs or specify that a software test driver shall be used in their stead (obvious examples of affected tests in this case include "rudder response", "dutch roll" and "steady state sideslip", but be aware that other, less-obvious tests such as "minimum control speed", "spiral stability" and "engine inoperative trim" can also be affected).

The following tests apply to a Level C or D helicopter simulator, delete for lower-fidelity helicopter simulators:

Test 1i Autorotational entry from cruise or climb
Test 2b Low airspeed handling qualities, trimmed flight control positions, translation in ground effect
Test 2b Low airspeed handling qualities, critical azimuth, stationary hover
Test 2b Low airspeed handling qualities, longitudinal control response, step input, hover
Test 2b Low airspeed handling qualities, lateral control response, step input, hover
Test 2b Low airspeed handling qualities, directional control response, step input, hover
Test 2b Low airspeed handling qualities, vertical control response, step input, hover

7. If the tolerances that are included in the "Airplane Flight Simulator Evaluation Handbook" or "Helicopter Simulator Qualification" Advisory Circular are acceptable for the tests to be conducted, delete the phrase "as amended by the following" that follows (7). Otherwise retain this phrase.

8. If the phrase following (7) is retained, list the specific exceptions to the commercial tolerances using a tabular format.

9. Insert in blank (9) any requirements that are to be verified by analysis; e.g., "the rotor aerodynamic model is sufficiently robust to simulate all required flight conditions".

10. Insert in blank (10) any requirements that are to be verified by demonstration; e.g., "air combat maneuvers and helicopter dynamics with the rotor partially submerged in turbulent airwakes".

EXAMPLES

Example 1. A simulator for a single-engine fighter aircraft. This aircraft is a superaugmented, computer-controlled aircraft. All flight controls are either replicated or depicted (i.e., interactive with the simulation). This continues the example of paragraph 3.7.3.1.1.

3.7.3.1.2 Flight Performance and Flying Qualities. The simulated air vehicle shall respond to flight and powerplant controls, and the synthetic environment in accordance with the requirements of this specification and the approved design criteria. The effect of aerodynamic changes for various combinations of drag and thrust encountered in flight shall be simulated; this shall include the effect of changes in air vehicle attitude, aerodynamic and propulsive forces and moments, altitude, temperature, gross weight, center of gravity location, airframe icing, nonlinearities due to sideslip, and configuration to include external load operations.

4.2.1.7.3.1.2 Verification of Flight Performance and Flying Qualities. This requirement shall be verified by test. Flight performance and flying qualities simulation shall be verified by test in accordance with the procedures of the "Airplane Flight Simulator Evaluation Handbook" as follows:

Section 1c Normal climb, all engines operating
Section 1c Level flight acceleration; Military Power and Afterburner power levels shall be tested
Section 1c Level flight deceleration
Section 1d Cruise performance
Section 1f Engine acceleration on approach or landing; however, throttles shall be advanced to the Military Power setting
Section 1f Engine deceleration on the ground; however throttles shall be set to the Afterburner setting initially
Section 2b Small control inputs during cruise, yaw
Section 2b Small control inputs during cruise, pitch
Section 2b Small control inputs during cruise, roll
Section 2b Small control inputs on approach, yaw
Section 2b Small control inputs on approach, pitch
Section 2b Small control inputs on approach, roll
Section 2c Power change dynamics on approach
Section 2c Flap change dynamics during second to third segment climb, retraction
Section 2c Flap change dynamics on approach, extension
Section 2c Spoiler/speedbrake change dynamics during cruise, extension
Section 2c Spoiler/speedbrake change dynamics during cruise, retraction
Section 2c Gear change dynamics during first to second segment climb, retraction
Section 2c Gear change dynamics on approach, extension
Section 2c Gear operating times during takeoff, retraction
Section 2c Gear operating times on approach, extension
Section 2c Alternate gear operating times on approach, extension
Section 2c Flap operating times on the ground, retraction
Section 2c Flap operating times on approach, extension
Section 2c Alternate flap operating times on the ground, retraction
Section 2c Alternate flap operating times on approach, extension
Section 2c Longitudinal trim during cruise, approach, and landing
Section 2c Longitudinal maneuver stability during cruise, approach, and landing
Section 2c Longitudinal static stability on approach
Section 2c Stick shaker, buffet, and stall speeds during second segment climb and landing
Section 2c Phugoid dynamics during cruise
Section 2c Short period dynamics during cruise
Section 2d Minimum control speed during landing or takeoff (whichever is more critical)
Section 2d Roll response during cruise and landing (or approach)
Section 2d Step input of cockpit roll controller during landing (or approach)
Section 2d Spiral stability during cruise
Section 2d Rudder response during landing (or approach)
Section 2d Dutch roll dynamics during cruise and landing (or approach)
Section 2d Steady state sideslip during landing (or approach)
Section 2i Minimum speed protection during takeoff, cruise, and approach (or landing)
Section 2i Load factor protection during takeoff and cruise
Section 2i Angle of attack protection during second segment climb and approach

The tolerances in the "Airplane Flight Simulator Evaluation Handbook", as amended by the following, shall apply.

Flight control forces
Longitudinal and lateral: 0.5 lb or 10%

Pedal: 2.0 lb or 10%

Calibrated airspeed

Specific reference values (e.g., minimum control speed): 2 knots

Otherwise the "Airplane Flight Simulator Evaluation Handbook" tolerance applies.

3.7.3.1.3 Departure and Spin Characteristics. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES

This requirement is not applicable.

-OR-

High angle of attack flight characteristics shall be simulated in accordance with the approved design criteria. This shall include stall characteristics, departure from controlled flight, spin entry, and recovery from departed flight and developed spin conditions.

4.2.1.7.3.1.3 Verification of Departure and Spin Characteristics. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test and demonstration.

Test shall verify that simulation of lift, angle of attack, and stall-related factors are comparable to the aircraft. Record airspeed, altitude, wind speed, all control surface positions, angle of attack, longitudinal, lateral, and normal body accelerations, aircraft roll, pitch, and yaw attitudes and rates. Complete an entry to a spin followed by recovery to controlled flight following the same profile as used in obtaining the approved aircraft data. Overlay the approved time history aircraft data with the simulator test results. Determine that recorded simulator parameter values changed in the same direction as the approved aircraft data for like control inputs and configuration.

Simulation of aircraft response during departure from controlled flight, spin entry, and recovery from departed flight and developed spin conditions shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3.

RATIONALE

The commercial requirements cited in the "Flight Performance and Flying Qualities" paragraph include simulation of entry into stall conditions, and a test for validating stick shaker, buffet, and stall speeds. The current paragraph provides for extension of the simulation into post-stall departure and spin.

Requirements Guidance: *Choose the first or second alternative in accordance with the user requirements for this device.*

Verification Guidance: *Choose the first or second alternative, as appropriate. If the approved data are reasonably accurate and consistent, tolerances should be levied on critical parameters that are consistent with the quality of the data. More typically, quality data in this flight regime is sparse; if quality data are lacking, it makes little sense to do more than verify that the simulation matches the trends in the approved data. At the very least, the quality of the data and the simulation should assure that pilot actions in the simulator will provide results that are consistent with the aircraft.*

3.7.3.1.4 Flight Control System. The simulator flight control system shall __1__. Operation of the controls shall result in simulated vehicle responses in accordance with the approved design criteria and the requirements of this specification. __2__

4.2.1.7.3.1.4 Verification of Flight Control System. This requirement shall be verified by demonstration and test. Tests and demonstrations conducted in conjunction with verification requirements defined elsewhere in this specification shall verify simulated vehicle response resulting from operation of primary and secondary controls.

Simulation of automatic flight control systems shall be demonstrated in conjunction with the verification of air vehicle simulation in paragraph 3.7.3.

RATIONALE

Requirements Guidance:
1. Normally the following would be put into blank (1): "operate as in the aircraft and include all primary, secondary, and automatic flight control systems in accordance with the approved design criteria and the requirements of this specification."

2. The required level of fidelity of the flight controls, which is defined elsewhere in this specification (see "Flight Controls" under "Air Vehicle Crew Systems"), should be checked to determine whether the simulation of certain flight control system functions is affected. If, for example, the flight control pedals' level of fidelity is defined as 'inert' or 'not required', it is not sufficient to specify a nominal rudder position that is static. For this example, the following might be inserted in blank (2): "The flight control system shall assume rudder control inputs which establish coordinated turns in lieu of an active pedal control interface." As an alternative, such decisions could be left "to be determined", and then incorporated into this specification once all effects are identified and the appropriate implementation is decided upon. If there are no 'inert', 'pictorial', or 'not required' flight controls, delete blank (2).

Verification Guidance: *Tests of the integrated simulated air vehicle response are conducted in the other subparagraphs of this section. Verification of autoflight system performance is typically accomplished by a series of subjective evaluations, rather than measurement; subject matter experts should evaluate all autoflight modes, functions, and characteristics as a part of the demonstration of air vehicle simulation in paragraph 3.7.3.*

Process Guidance: *If decisions regarding a non-interfaced control's inputs are left "to be determined", a process needs to be defined which will accomplish their determination. The Statement of Work should task the contractor to update this specification to document the decision, once determined.*

EXAMPLES
Example 1. The flight control pedals are to be inert in a low-cost, selective-fidelity device. The following might apply in the System Specification before an appropriate representation of the non-interfaced pedal inputs is decided:

3.7.3.1.4 Flight Control System. The simulator flight control system shall operate as in the aircraft and include all primary, secondary, and automatic flight control systems in accordance with the approved design criteria and the requirements of this specification. Operation of the controls shall result in simulated vehicle responses in accordance with the approved design criteria and the requirements of this specification. The rudder control inputs to be assumed by the flight control system in lieu of an active pedal control interface are to be determined.

Example 2. The flight control pedals are to be inert in a low-cost, selective-fidelity device. The following might apply in the PIDS after the non-interfaced pedal inputs are determined:

3.7.3.1.4 Flight Control System. The simulator flight control system shall operate as in the aircraft and include all primary, secondary, and automatic flight control systems in accordance with the approved design criteria and the requirements of this specification. Operation of the controls shall result in simulated vehicle responses in accordance with the approved design criteria and the requirements of this specification. The flight control system shall assume rudder control inputs which establish coordinated turns in lieu of an active pedal control interface.

3.7.3.2 Air Vehicle Powerplant. The fidelity of the simulation of the air vehicle powerplant system shall be in accordance with the subparagraphs of this paragraph. Unless otherwise specified, the following definitions shall apply as the minimum required levels of fidelity:

a. Replicated -- Provides performance identical to that of the air vehicle powerplant system or particular subsystem as defined by the design criteria and limited by other requirements of this specification (e.g., the fidelity of the controls) across the entire operating spectrum of the particular powerplant system or subsystem.

b. Partially Replicated -- Provides performance identical to that of the air vehicle powerplant system or particular subsystem as defined by the design criteria and limited by other requirements of this specification (e.g., the fidelity of the controls) for certain modes of the particular powerplant system's or subsystem's operation.

c. Approximated -- Provides performance that is similar but not necessarily identical to the air vehicle powerplant system or subsystem as defined by the design criteria.

d. Not Required -- No simulation is required except that necessary to provide the nominal inputs necessary for other systems or subsystems to meet the requirements of this specification.

4.2.1.7.3.2 Verification of Air Vehicle Powerplant. Verification of this requirement is not applicable.

RATIONALE

This is an introductory paragraph to the section that defines the required levels of fidelity in descending order for the simulation of air vehicle powerplant systems. Requirements for control fidelity are not included here, but rather in the paragraph dealing with the simulation requirements for the relevant controls.

When a system must be replicated, the complete performance of the aircraft system must be captured in the simulation. Replication implies a complete model of the actual aircraft system, function, or mode. The model must include all relevant characteristics, including control logic, delays and time constants, effects of bleed and horsepower extracticn, effects of altitude, airspeed and temperature, etc. which affect the operators' perception of system operation.

When a system must be partially replicated, the complete performance of the aircraft system must be captured in the simulation -- but only over a part of its operation. For example, it may not be necessary to simulate ground starts if simulation of ground operations is not required. In this case the extent of partial replication must be defined.

When a system must be approximated, only key elements of the performance must be captured. For example, the effects of bleed and horsepower extraction on thrust might be neglected. When a system is approximated the extent of approximation must be defined.

When a system simulation is not required, it still may be necessary to provide information from that system to another system. For example if the ignition system were not simulated (e.g., the ignition switches and indicators are 'pictorial'), it must still provide an input to the starting system and propulsion system. The input could be derived from the electrical power system.

3.7.3.2.1 Starting System. The starting system shall be __1__.

4.2.1.7.3.2.1 Verification of Starting System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required starting system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing and demonstration required elsewhere in this specification.

RATIONALE
Requirements Guidance:

1. Select one of the following:

a. "replicated. The simulation shall provide a complete model of the starting system, as well as a complete set of interfaces with other aircraft systems."

b. "partially replicated. The simulation shall provide a model of the starting system, as well as a set of interfaces with other aircraft systems that are necessary to satisfy other requirements of this specification."

c. "not required. The simulation shall be initialized with the engine(s) running."

Verification Guidance: *Select the first alternative if the fidelity required is replicated. Select the second alternative if the fidelity is partially replicated or not required.*

3.7.3.2.2 Ignition System. The ignition system shall be __1__.

4.2.1.7.3.2.2 Verification of Ignition System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required ignition system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing and demonstration required elsewhere in this specification.

RATIONALE

Requirements Guidance:

1. Select one of the following:

a. "replicated. The simulation shall provide a complete model of the ignition system, as well as a complete set of interfaces with other aircraft systems."

b. "partially replicated. The simulation shall provide a model of the ignition system, as well as a set of interfaces with other aircraft systems that are necessary to satisfy other requirements of this specification."

c. "not required. The simulation shall assume that __2__."

2. If 1c is selected, insert the appropriate assumption in blank (2). For example, "the ignition switches are in the NORM position" or "the ignition switches are in the position which supplies continuous power to the ignition exciters".

Verification Guidance: *Select the first alternative if the fidelity required is replicated. Select the second alternative if the fidelity is partially replicated or not required.*

3.7.3.2.3 Propulsion System. The propulsion system shall be __1__.

4.2.1.7.3.2.3 Verification of Propulsion System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required propulsion system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing and demonstration required elsewhere in this specification.

RATIONALE

Requirements Guidance:

1. Select one of the following:

a. "replicated. The simulation shall provide a complete model of the propulsion system, as well as a complete set of interfaces with other aircraft systems."

b. "partially replicated. The simulation shall provide a model of the propulsion system, as well as a set of interfaces with other aircraft systems that are necessary to satisfy other requirements of this specification."

c. "approximated. The simulation shall provide a model of the propulsion system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification."

Verification Guidance: *Select the first alternative if the fidelity required is replicated. Select the second alternative if the fidelity is partially replicated or approximated.*

3.7.3.3 Air Vehicle Mission Management Systems. The fidelity of the simulation of the mission management system shall be in accordance with the subparagraphs of this paragraph. Unless otherwise specified, the following definitions shall apply as the minimum required levels of fidelity:

a. Replicated -- Provides performance identical to that of the aircraft mission management system or particular subsystem as defined by the design criteria and limited by other requirements (e.g., the synthetic environment) of this specification across the entire operating spectrum of the particular mission management system or subsystem.

b. Partially Replicated -- Provides performance identical to that of the aircraft mission management system or particular subsystem as defined by the design criteria and limited by other requirements (e.g., the synthetic environment) of this specification for certain modes of the particular mission management system's or subsystem's operation.

c. Approximated -- Provides performance that is similar but not necessarily identical to aircraft mission management system or subsystem as defined by the design criteria.

d. Not Required -- No simulation is required except that necessary to provide the nominal inputs necessary for other systems or subsystems to meet the requirements of this specification.

4.2.1.7.3.3 Verification of Air Vehicle Mission Management Systems. Verification of this requirement is not applicable.

RATIONALE
This is an introductory paragraph to the section that defines the required levels of fidelity in descending order for the simulation of mission management systems. Requirements for control fidelity are not included here, but rather in the paragraph dealing with the simulation requirements for the relevant controls.

When a system must be replicated, the complete performance of the aircraft system must be captured in the simulation. Replication implies a complete model of the actual aircraft system, function, or mode. The model must include all relevant characteristics, including control logic, time delays, antenna effects, frequency and bandwidth effects, etc. that affect the operator's perception of system operation.

When a system must be partially replicated, the complete performance of the aircraft system must be captured in the simulation -- but only over a part of its operation. For example, it may not be necessary to simulate the maintenance and test modes of a particular system. In this case, the extent of partial replication must be defined.

Replication and partial replication of avionics systems involving digital logic or computers may be accomplished with a stimulation (use of actual hardware) or emulation approach (see paragraph 3.7.3.3.1). The level of fidelity is one of the trade-offs.

When a system must be approximated, only key elements of the performance must be captured. For example, an inertial navigation simulation could merely report the simulated aircraft's position neglecting drift errors, etc. When a system is approximated, the extent of approximation must be defined.

When a system simulation is not required, it still may be necessary to provide information from that system to another system. For example, the Global Position System is not simulated but it must provide an input to the mission computer. The input could be derived from the inertial navigation system.

3.7.3.3.1 Avionics Systems.

4.2.1.7.3.3.1 Verification of Avionics Systems. Verification of this requirement is not applicable.

RATIONALE
This is a lead-in paragraph only.

ISSUES REGARDING AVIONICS IN SIMULATORS (FUNCTIONAL SIMULATION VERSUS EMULATION VERSUS STIMULATION):

Aircraft avionics pose a difficult problem for simulators. As the aircraft hardware and software are modified, the simulator components must likewise be modified concurrently to provide appropriate training. Frequently simulator modifications lag the aircraft by an unacceptable period of time. This is an ongoing problem for the Air Force. A method is needed to reduce the time between the release of a new version of flight software and the release of a simulator equivalent to that software. The use of actual flight software in the simulator could reduce both the required simulator lead time and the cost of producing and upgrading the simulator, but that approach is not without its problems.

The basic problem in trying to use flight software in a simulator environment is that unmodified flight software is normally not designed for external control. This precludes many simulator-unique functions (simulator-unique functions include freeze, malfunctions, position reset and initialization, etc.). One design solution is to modify the flight software so that it contains the required simulator-unique functions. In order to use the modified flight software in a simulator environment, such software must fit within the execution time and memory constraints of the aircraft computer (or its equivalent) as adapted to the simulator environment. In addition, the modifications must be incorporated into any revisions that the flight software undergoes.

Flight software includes a complex, specialized computer operating system and multiple functions that often reside in multiple processors. In order to use the unmodified flight software in a simulator environment, such software must be stimulated and controlled from a simulator computer outside of the normal aircraft configuration. It is very difficult to choose and implement a simulation approach that optimally balances acquisition costs, simulator-unique functions, and supportability. (Supportability, in the present context, is the issue of updating the simulator when the aircraft software is updated.)

Even if one uses the airborne processor, not all software changes can be used directly. The processor and associated software used in airborne applications are generally not designed for ready incorporation of simulator-unique functions. (Simulator-unique functions have, on one occasion, been included in the aircraft software. This was possible due to the fortuitous availability of maintenance ports on the processor that were used to provide the interface to simulator-unique functions.) Acquisition costs are impacted by the use of onboard processors in the simulator -- not only due to the expense and limited availability of the aircraft equipment, but also due to the requirement to create the complete environmental interface (inputs and outputs required to make the airborne software function, but not otherwise needed for the simulation).

Functional simulation, on the other hand, leads to a significant level of redesign whenever major software changes are made. This brings with it both the expense and the time required to accomplish the update.

***Process Guidance:** Appropriate decision points must be identified regarding tradeoffs and decisions leading to the design solution for avionics simulation.*

3.7.3.3.1.1 Avionics Architecture. Avionics architecture shall comply with all requirements of this specification and shall facilitate rapid updates due to aircraft changes. ____1___.

4.2.1.7.3.3.1.1 Verification of Avionics Architecture. This requirement shall be verified by inspection and analysis. During the development process analysis of the design and inspection of drawings shall demonstrate compliance with the requirements of this specification. Analyses shall specifically address updatability with aircraft changes to show that the technical features of the simulator design facilitate rapid update.

RATIONALE

This paragraph reiterates key concerns with the simulator's avionics systems. The four most important are:

a. They must provide the fidelity required in other subparagraph of paragraph 3.7.3.3. Where fidelity is defined by the levels of paragraph 3.7.3.3.

b. The architecture must map to the actual aircraft as stated in paragraph 3.4.

c. The avionics simulation must meet requirements of paragraph 3.2.1.1, Modes, 3.2.1.2, Events, and 3.2.1.3, Activities. These include many simulator unique requirements not needed in actual aircraft.

d. They must be easily updatable with aircraft changes.

Items a to c are accomplished by the statement "comply with all requirements of this specification."

Requirements Guidance:

1. Until the simulator avionics architecture is defined and agreed to this blank should be deleted. After the avionics architecture is defined the specification should be updated to provide a description. The description should identify specific actual aircraft components and systems used in the simulator as the approach to meeting fidelity requirements for other components.

Process Guidance: *When the simulator avionics architecture is defined the Statement of Work should require a specification update.*

EXAMPLES
Example 1 System specification before architecture is identified.

3.7.3.3.1.1 Avionics Architecture Avionics architecture shall comply with all requirements of this specification and shall facilitate rapid updates due to aircraft changes.

Example 2 PIDS after architecture is defined

3.7.3.3.1.1 Avionics Architecture Avionics architecture shall comply with all requirements of this specification and shall facilitate rapid updates due to aircraft changes. An actual aircraft mission computer, stores management set, and Heads Up Display shall be incorporated into the simulator. The actual aircraft Mil -STD 1556 bus shall also be incorporated. A single mission computer shall be used in lieu of the dual aircraft configuration with the second computer's Operational Flight Program operating in available spare time. All other avionics systems shall be simulated software and interfaced with the MIL-STD 1556 bus by commercially available bus interface units.

3.7.3.3.1.2 Integration. The intergation of aircraft avionics functions ___1___. ___2___.

4.2.1.7.3.3.1.2 Verification of Integration. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that all avionics functions interact to provide the fidelity across the spectrum of use as required by this specification.

RATIONALE

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity. "Not required" will rarely be an appropriate choice.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
3.7.3.3.1.2 Integration The integration of aircraft avionics functions shall be partially replicated. The maintenance, test and data recording functions are not required. Other functions shall be replicated.

3.7.3.3.1.2.1 Mission Control Functions (MCFs). Mission Control functions of the aircraft shall be ___1___. ___2___.

4.2.1.7.3.3.1.2.1 Verification of Mission Control Functions (MCFs). CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that all mission control functions provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Mission Control functions are those needed for aircraft and weapons safety.

Requirements Guidance:

1. *Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.*

2. *Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.*

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
Example 1 Full scale Weapons System Trainer

3.7.3.3.1.2.1 Mission Control Functions (MCFs) Mission Control functions of the aircraft shall be replicated.

Example 2 Avionics Part Task Trainer

3.7.3.3.1.2.1 Mission Control Functions (MCFs) Mission Control functions of the aircraft shall be approximated.

3.7.3.3.1.2.2 Offensive/Defensive Functions. Offensive/Defensive functions of the aircraft ___1___. ___2___.

4.2.1.7.3.3.1.2.2 Verification of Offensive/Defensive Functions. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that all offensive and defensive functions provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Offensive/Defensive functions are any avionics functions or subfunctions that may be used in any combination to attack, defend, or simultaneously attack and defend as required by aircraft mission needs. They include Electronic Countermeasures, stealth, emission control, weapon control. Full simulation of these functions requires an interactive simulation environment.

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
A part task trainer for air to ground weapons delivery.

3.7.3.3.1.2.2 Offensive/Defensive Functions Offensive/Defensive functions of the aircraft shall be partially replicated. The offensive air to ground functions shall be replicated. The offensive air to air functions are not required. Chaff, flares, and jammers are not required.

3.7.3.3.1.2.3 Operational Flight Programs (OFPs). Functions of the aircraft operational flight program (s) ___1___. ___2___.

4.2.1.7.3.3.1.2.3 Verification of Operational Flight Programs (OFPs). CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that functions of the aircraft OFP (s) provide the fidelity across the spectrum of use as required by this specification.

RATIONALE

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
A lower fidelity training device.

3.7.3.3.1.2.3 Operational Flight Programs (OFPs) Functions of the aircraft operational flight program shall be approximated. Control inputs shall provide the same information in the same sequence on displays as

defined by design criteria. Time delays between control input and display response need not match design criteria but shall not exceed 0.5 seconds. Maintenance and test functions are not required.

3.7.3.3.1.2.4 Data Transfer System. The aircraft data transfer system ___1___. ___2___.

4.2.1.7.3.3.1.2.4 Verification of Data Transfer System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. This requirement shall be verified by test which shall verify that all data can be transferred as required by this specification.

RATIONALE
Data transfer systems are data storage media (magnetic tapes, Magnetic tape cartridges, magnetic discs optical discs, etc.) and an aircraft system to read them. They are used to load or aircraft operational flight programs and data.

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity. If the level of fidelity is "replicated" or "partially replicated" state whether or not actual aircraft tapes, cartridges, etc must be used in the simulator

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
Example 1 Full fidelity system with use of actual aircraft cartridges required.

3.7.3.3.1.2.4 Data Transfer System The aircraft data transfer system shall be replicated. Actual aircraft data cartridges shall be useable in the simulator.

Example 2 Limited fidelity system with use of actual aircraft cartridges not required. In this case an interface with simulation control system of paragraph 3.7.4 for loading appropriate data.

3.7.3.3.1.2.4 Data Transfer System The aircraft data transfer system shall be approximated. Actual aircraft data cartridges need not be useable in the simulator. Data files to provide shall be loaded into the simulator in accordance with paragraph 3.7.4.4.

Example 3 High fidelity system with use of actual aircraft cartridges required. In this case an interface with simulation control system of paragraph 3.7.4 for loading appropriate data.

3.7.3.3.1.2.4 Data Transfer System The aircraft data transfer system shall be partially replicated. Actual aircraft data cartridges shall be useable in the simulator; however, they need not be loaded directly in the simulator cockpit but instead shall be loaded in accordance with paragraph 3.7.4.4.

3.7.3.3.1.2.5 Avionics Interfaces. Aircraft avionics interfaces ___1___. ___2___.

4.2.1.7.3.3.1.2.5 Verification of Avionics Interfaces. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by demonstration. The avionics interfaces shall exercised during other testing required by this specification.

RATIONALE
Avionics interfaces include MIL-STD- 1553 data busses, video distribution networks, avionics interfaces with flight controls, propulsion, etc.

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity. "Not required will rarely be an appropriate choice.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
An avionics part task trainer

3.7.3.3.1.2.5 Avionics Interfaces Aircraft avionics interfaces shall be partially replicated. Interfaces with the propulsion system are not required.

3.7.3.3.1.3 Communications. Aircraft communications ___1___ (2) in accordance with the following subparagraphs.

4.2.1.7.3.3.1.3 Verification of Communications. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that simulated communications provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Full simulation of communications requires that appropriate transmitters and receivers be included in the synthetic environment.

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity. "Not required" will rarely be an appropriate

choice. If the entire aircraft communication system is to be "replicated" or is "not required" all subsequent subparagraphs should be deleted. Otherwise use the highest level of fidelity needed in this blank.

2. Delete the final phrase if the level of fidelity is "replicated" or not required.

Verification Guidance: *If the degree of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES

Example 1 Full fidelity communication is required. Note in this case all subparagraphs should be deleted.

3.7.3.3.1.3 Communications Aircraft communications shall be replicated.

Example 2 Varying fidelity required for different communication subsystems.

3.7.3.3.1.3 Communications Aircraft communications partially replicated in accordance with the following subparagraphs.

3.7.3.3.1.3.1 Radio Management Function. CHOOSE ONE OF THE FOLLOWING

This requirement is not applicable

-OR-

Aircraft radio management functions ___1___. ___2___.

4.2.1.7.3.3.1.3.1 Verification of Radio Management Function. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify radio management functions provide the fidelity across the spectrum of use as required by this specification.

RATIONALE

Requirements Guidance: *Check the Rationale for paragraph 3.7.3.3.1.3 to ensure this paragraph is needed. Choose the first option if there is no radio management function in the aircraft.*

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the requirement is not applicable or the level of fidelity is "not required" use the first alternative otherwise use the second.*

Process Guidance:

EXAMPLES

3.7.3.3.1.3.1 Radio Management Function Aircraft radio management functions shall be partially replicated. The channel select function shall operate in accordance with the design criteria however the self test, channel add, and channel delete functions are not required.

3.7.3.3.1.3.2 Radio Communication. Aircraft radio communications ___1___. ___2___.

4.2.1.7.3.3.1.3.2 Verification of Radio Communication. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that the radio communications provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Radio Communications include LF, HF, VHF FM, VHF AM, UHF Line of Sight, UHF SATCOM, data links, JTIDS, Secure voice and data, intercoms, and public address systems.

Requirements Guidance: *Check the Rationale for paragraph 3.7.3.3.1.3 to ensue this paragraph is needed.*

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
3.7.3.3.1.3.2 Radio Communication Aircraft radio communications shall be approximated. The intercom shall be replicated. The AN/ARC 69 UHF Radio shall operate as described by design criteria; however its antenna shall be assumed to perfectly omni-directional. Other radios are not required.

3.7.3.3.1.3.3 Radio Identification. CHOOSE ONE OF THE FOLLOWING

This requirement is not applicable

-OR-

Aircraft radio identification functions ___1___. ___2___.

4.2.1.7.3.3.1.3.3 Verification of Radio Identification. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify radio identification functions provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Radio Identification includes Air Traffic Control Beacons, Identification Friend or Foe (IFF), etc.

Requirements Guidance: *Check the Rationale for paragraph 3.7.3.3.1.3 to ensure this paragraph is needed. Choose the first option if there is no radio identification function in the aircraft.*

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the requirement is not applicable or the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
3.7.3.3.1.3.3 Radio Identification Aircraft radio identification functions shall be partially replicated. All functions shall be replicated except the test function which is not required.

3.7.3.3.1.3.4 Traffic Alert/Collision Avoidance. CHOOSE ONE OF THE FOLLOWING

This requirement is not applicable

-OR-

Aircraft traffic alert and collision avoidance functions ___1___. ___2___.

4.2.1.7.3.3.1.3.4 Verification of Traffic Alert/Collision Avoidance. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify traffic alert and collision avoidance functions provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
These are interactive systems designed to prevent mid-air collisions. They are not currently installed in any military aircraft.

Requirements Guidance: *Check the Rationale for paragraph 3.7.3.3.1.3 to ensure this paragraph is needed. Choose the first option if there is no traffic alert or collision avoidance function in the aircraft.*

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the requirement is not applicable or the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES

3.7.3.3.1.3.4 Traffic Alert/Collision Avoidance Aircraft traffic alert and collision avoidance functions shall be partially replicated. All functions except the self test shall be replicated. The self test function is not required.

3.7.3.3.1.4 Navigation Systems. Aircraft navigation systems ___1___ (2) in accordance with the following subparagraphs.

4.2.1.7.3.3.1.4 Verification of Navigation Systems. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that simulated navigation systems provide the fidelity across the spectrum of use as required by this specification.

RATIONALE

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity. "Not required" will rarely be an appropriate choice. If the entire aircraft navigation system is to be "replicated" or is "not required" all subsequent subparagraphs should be deleted. Otherwise use the highest level of fidelity needed in this blank.

2. Delete the final phrase if the level of fidelity is "replicated" or not required.

Verification Guidance: *If the degree of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
Example 1 Full fidelity navigation is required. Note in this case all subparagraphs should be deleted.

3.7.3.3.1.4 Navigation Systems Aircraft navigation systems shall be replicated.

Example 2 Varying fidelity required for different navigation subsystems.

3.7.3.3.1.4 Navigation Systems Aircraft navigation systems shall be partially replicated in accordance with the following subparagraphs.

3.7.3.3.1.4.1 Long Range Navigation. CHOOSE ONE OF THE FOLLOWING

This requirement is not applicable

-OR-

Aircraft long range navigation systems ___1___. ___2___.

4.2.1.7.3.3.1.4.1 Verification of Long Range Navigation. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that simulated long range navigation systems provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Long range navigation systems include inertial navigation systems, the Global Positioning System (GPS), and VLF Omega. Full simulation of GPS requires satellites in the synthetic environment. Full simulation of VLF Omega requires that stations be included in the synthetic environment.

Requirements Guidance: *Check the Rationale for paragraph 3.7.3.3.1.4 to ensure this paragraph is needed. Choose the first option if there is no long range navigation system in the aircraft.*

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the requirement is not applicable or the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
3.7.3.3.1.4.1 Long Range Navigation Aircraft long range navigation systems shall be approximated. The inertial navigation system shall be replicated. The aircraft global positioning system shall operate as described by design criteria; however, the system shall provide perfect navigation (no deviation from aircraft state) in the "ON" mode.

3.7.3.3.1.4.2 Local Navigation. Aircraft local navigation systems ___1___. ___2___.

4.2.1.7.3.3.1.4.2 Verification of Local Navigation. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that simulated long range navigation systems provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Local Navigation systems include VHF Omni-directional Range (VOR), Distance Measuring Equipment (DME), TACAN, Low Frequency/Automatic Direction Finder (LF/ADF), UHF/VHF ADF and Station Keeping Equipment (SKE). Full simulation of these systems requires that stations be included in the synthetic environment.

Requirements Guidance: *Check the Rationale for paragraph 3.7.3.3.1.4 to ensure this paragraph is needed.*

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
3.7.3.3.1.4.2 Local Navigation Aircraft local navigation systems shall be partially replicated. All systems except the station keeping equipment shall be replicated. The station keeping equipment is not required.

3.7.3.3.1.4.3 Landing Aids. Aircraft landing aids ___1___. ___2___.

4.2.1.7.3.3.1.4.3 Verification of Landing Aids. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that simulated landing aids provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Landing Aids include Instrument Landing System (ILS) and Microwave Landing System (MLS). Full simulation of these systems requires that stations be included in the synthetic environment.

Requirements Guidance: *Check the Rationale for paragraph 3.7.3.3.1.4 to ensure this paragraph is needed.*

1. *Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.*

2. *Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.*

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
An air to air part task trainer

3.7.3.3.1.4.3 Landing Aids Aircraft landing aids shall be approximated. The instrument landing system (ILS) shall be powered and the self test function shall operate per design criteria. At all other times when the power is "ON" the system shall indicate that no station is tuned.

3.7.3.3.1.5 Standby Flight Instruments. Standby flight instruments ___1___. ___2___.

4.2.1.7.3.3.1.5 Verification of Standby Flight Instruments. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that simulated standby flight instrument provide the fidelity across the spectrum of use as required by this specification.

RATIONALE

Standby flight instruments include attitude heading reference systems and magnetic compasses.

Requirements Guidance:

1. Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.

2. Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

EXAMPLES
3.7.3.3.1.5 Standby Flight Instruments Standby flight instruments shall be approximated. The standby ADI and magnetic compass shall be powered as described by design criteria. No other functions are required.

3.7.3.3.1.6 Sensors.

4.2.1.7.3.3.1.6 Verification of Sensors. Verification of this requirement is not applicable.

RATIONALE
This is a title only lead in paragraph.

3.7.3.3.1.6.1 Radar Systems. CHOOSE ONE OF THE FOLLOWING

The aircraft ___1___ ___2___. ___3___. ___4___.

-OR-

The aircraft radar systems shall be simulated as required by the following subparagraphs.

4.2.1.7.3.3.1.6.1 Verification of Radar Systems. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that the simulated ___ 5___ provide(s) the fidelity across the spectrum of use as required by this specification.

RATIONALE
Radar systems include fire control radars, attack radars, tail warning radars, radar altimeters, radar beacons, high resolution mapping radars, doppler velocity sensors, radar warning receivers, panoramic receivers,doppler velocity sensors, terrain following/terrain avoidance radars, weather radars, and multi-mode radars. Full simulation of these systems may require a complex interactive synthetic environment and complex cue generators.

Requirements Guidance: *Most aircraft will have more than one of these radar systems. The functions can be radically different. We recommend a specific requirement for each radar system or related group of systems be included in the specification. This may be accomplished with either of the two choices shown. The second option is recommended when there are several radar systems and the first becomes*

cumbersome. When using the second choice subparagraphs should be added for each major system. Each subparagraph should follow the instructions for blanks 1 to 3 below. Care must be taken to include all radar systems.

Requirements Guidance:

1. *Name the appropriate system.*

2. *Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.*

3. *Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.*

4. *If it is not cumbersome repeat blanks 1 to 3 for each succeeding system*

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

5. *Name the appropriate system or use "each radar system" if blank 4 above is used.*

Note that if subparagraphs are used in the requirements section appropriate subparagraphs following the above guidance should also be included.

EXAMPLES
Example 1. Few radars on the aircraft

3.7.3.3.1.6.1 Radar Systems The aircraft attack radar shall be partially replicated. Air to ground modes shall be replicated, but air to air and weather modes are not required. The radar warning receiver shall be replicated.

Example 2. Several radars on the aircraft

3.7.3.3.1.6.1 Radar Systems The aircraft radar systems shall be simulated as required by the following subparagraphs.

3.7.3.3.1.6.1.1 Attack Radar The aircraft attack radar shall be partially replicated. Air to ground modes shall be replicated, but air to air and weather modes are not required.

3.7.3.3.1.6.1.2 Terrain Following/ Terrain Avoidance Radar - The aircraft terrain following/ terrain avoidance radar shall be replicated.

3.7.3.3.1.6.1.3 Radar Warning Receiver - The aircraft radar warning receiver shall be partially replicated. All functions except self test shall be replicated. Self test is not required.

3.7.3.3.1.6.1.4 Tail Warning Radar The aircraft tail warning radar is not required.

3.7.3.3.1.6.1.4 Radar Altimeter The aircraft radar altimeter shall be replicated.

3.7.3.3.1.6.2 Electro-Optics. CHOOSE ONE OF THE FOLLOWING ALTERNATIVES:

The aircraft ___1___ ___2___. ___3___. ___4___.

-OR-

The aircraft electro- optical systems shall be simulated as required by the following subparagraphs.

4.2.1.7.3.3.1.6.2 Verification of Electro-Optics. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify that the simulated ___ 5___ provide(s) the fidelity across the spectrum of use as required by this specification.

RATIONALE
Electro-optical systems include target imaging sensors, target non-imaging sensors, navigation imaging sensors, navigation non-imaging sensors, reconnaissance sensors, and warning systems, Some typical sensors are forward looking infrared, television cameras, target illuminators and designators, altimeters, laser range finders, and laser detection and ranging systems. Full simulation of these systems may require a complex interactive synthetic environment and complex cue generators.

Requirements Guidance: *Some aircraft will have more than one electro-optical system. The functions can be radically different. We recommend a specific requirement for each radar system or related group of systems be included in the specification. This may be accomplished with either of the two choices shown. The second alternative is recommended when there are several systems and the first becomes cumbersome. When using the second choice subparagraphs should be added for each major system. Each subparagraph should follow the instructions for blanks 1 to 3 below. Care must be taken to include all electro-optical systems.*

Requirements Guidance:

1. *Name the appropriate system.*

2. *Fill in the blank "shall be replicated", "shall be partially replicated"," shall be approximated", or "are not required" as necessary to provide the necessary fidelity.*

3. *Where the level of fidelity is "approximated" or "partially replicated" describe the extent of the fidelity.*

4. *If it is not cumbersome repeat blanks 1 to 3 for each succeeding system*

Verification Guidance: *If the level of fidelity is "not required" use the first alternative otherwise use the second.*

5. *Name the appropriate system or use "each electro-optical system" if blank 4 above is used.*

Note that if subparagraphs are used in the requirements section appropriate subparagraphs following the above guidance should also be included.

EXAMPLES
3.7.3.3.1.6.2 Electro-Optics The aircraft forward looking infrared and low light level television systems shall be partially replicated. These systems shall replicate the "SCAN" mode of operation. Power up logic and self test modes are not required.

3.7.3.3.1.6.3 Instrumentation Sensors. Instrumentation sensors ___1___. ___2___.

4.2.1.7.3.3.1.6.3 Verification of Instrumentation Sensors. This requirement shall be verified by test. The test shall verify that simulated instrumentation sensors provide the fidelity across the spectrum of use as required by this specification.

RATIONALE
Instrumentation sensors include attitude, horizontal situation, airspeed/mach, vertical velocity, altimetry, acceleration, angle of attack, turn and slip, outside air temperature, tachometer, engine temperature, fuel flow, oil pressure, oil quantity, engine pressure ratio, nozzle position, hydraulic pressure, flap position, trim position, speed brake position, landing gear position, fuel quantity, oxygen quantity, cabin pressure, data recorders, etc.

EXAMPLES
3.7.3.3.1.6.3 Instrumentation Sensors Instrumentation sensors shall be partially replicated. All sensors except the data recorder shall be replicated. The data recorder is not required.

3.7.3.4 Air Vehicle Utility Management Systems.

4.2.1.7.3.4 Verification of Air Vehicle Utility Management Systems. Verification of this requirement is not applicable.

RATIONALE
This is a title only lead in paragraph.

3.7.3.4.1 Electrical Power System. The electrical power system shall be __1__.

4.2.1.7.3.4.1 Verification of Electrical Power System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required electrical system features shall be exercised. Operation of all circuit breakers shall be verified.

-OR-

This requirement shall be verified by demonstration in conjunction with testing required by this specification.

RATIONALE
In past simulators, the electrical system fidelity has generally been partially replicated or approximated as discussed below. Several companies now have approaches that allow the generation of simulation software code directly from electrical system diagrams.

Requirements Guidance:

1. *Select one of the following:*

   a. *"Replicated. The simulation shall provide a complete model of the aircraft electrical system including alternators, generators, circuit breakers, switches, etc., as well as a complete set of interfaces with other aircraft systems. All circuit breakers usable by the crew shall be operational. Transient and electrical load effects shall be modeled."*

   b. *"Partially Replicated. The simulation shall provide a model of the aircraft electrical system including alternators, generators, circuit breakers, switches, etc., and interfaces with other aircraft*

systems that are necessary to satisfy other requirements of this specification. The following circuit breakers shall be operational: __2__. Electrical load effects shall be modeled."

c. "Approximated. The simulation shall provide a model of the electrical system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification. __2__."

d. "Not Required. The simulation shall assume full power is available at all times."

2. If the fidelity is partially replicated, identify the circuit breakers to be operational. If the fidelity is approximated, it may be appropriate to further discuss the degree of approximation.

Verification Guidance: *Select the first alternative if the fidelity required is replicated or partially replicated. Select the second if the fidelity is approximated or not required.*

Process Guidance: *Specific circuit breakers may need to be identified after contract award. If this is the case, a process needs to be defined which will accomplish their identification and subsequent documentation as an update to this specification.*

EXAMPLES
A full weapons system trainer.

3.7.3.4.1 Electrical Power System. The electrical power system shall be partially replicated. The simulation shall provide a model of the aircraft electrical system including alternators, generators, circuit breakers, switches, etc., and interfaces with other aircraft systems that are necessary to satisfy other requirements of this specification. The following circuit breakers shall be operational: Right Main Circuit Breaker (CB), Left Main CB, Main DC CB, Right Hydraulic Pump CB, and Left Hydraulic Pump CB. Electrical load effects shall be modeled.

4.2.1.7.3.4.1 Verification of Electrical Power System. This requirement shall be verified by test. All required electrical system features shall be exercised. Operation of all circuit breakers shall be verified.

3.7.3.4.2 Hydraulic Power System. The hydraulic power system shall be __1__.

4.2.1.7.3.4.2 Verification of Hydraulic Power System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required hydraulic system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing required by this specification.

RATIONALE
In past simulators, the hydraulic system fidelity has generally been partially replicated or approximated as discussed below. Several companies now have approaches that allow the generation of simulation software code directly from electrical system diagrams, and it is likely in the future these approaches may apply to hydraulic systems.

Requirements Guidance:

1. Select one of the following:

a. "Replicated. The simulation shall provide a complete model of the aircraft hydraulic system including reservoirs, pumps, valves, actuators, etc., as well as a complete set of interfaces with other aircraft systems. Transient and hydraulic load effects shall be modeled."

b. "Partially Replicated. The simulation shall provide a model of the aircraft hydraulic system including reservoirs, pumps, valves, actuators, etc., and interfaces with other aircraft systems that are necessary to satisfy other requirements of this specification. Hydraulic load effects shall be modeled."

c. "Approximated. The simulation shall provide a model of the hydraulic system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification."

d. "Not Required. The simulation shall assume full power is available at all times."

Verification Guidance: *Select the first alternative if the fidelity required is replicated or partially replicated. Select the second if the fidelity is approximated or not required.*

EXAMPLES
A typical requirement for a high-fidelity Weapons System Trainer.

3.7.3.4.2 Hydraulic Power System. The hydraulic power system shall be replicated. The simulation shall provide a complete model of the aircraft hydraulic system including reservoirs, pumps, valves, actuators, etc., as well as a complete set of interfaces with other aircraft systems. Transient and hydraulic load effects shall be modeled.

4.2.1.7.3.4.2 Verification of Hydraulic Power System. This requirement shall be verified by test. All required hydraulic system features shall be exercised.

3.7.3.4.3 Pneumatic Power System. The pneumatic power system shall be __1__.

4.2.1.7.3.4.3 Verification of Pneumatic Power System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required hydraulic system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing required by this specification.

RATIONALE
Several companies now have approaches that allow the generation of simulation software code directly from electrical system diagrams, and it is likely these approaches may apply to pneumatic systems in the future.

Requirements Guidance:

1. Select one of the following:

a. "Replicated. The simulation shall provide a complete model of the aircraft pneumatic system including reservoirs, pumps, valves, actuators, etc., as well as a complete set of interfaces with other aircraft systems. Transient and pneumatic load effects shall be modeled."

b. "Partially Replicated. The simulation shall provide a model of the aircraft pneumatic system including reservoirs, pumps, valves, actuators, etc., and interfaces with other aircraft systems that are necessary to satisfy other requirements of this specification. Pneumatic load effects shall be modeled."

c. "Approximated. The simulation shall provide a model of the pneumatic system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification."

d. "Not Required. The simulation shall assume full power is available at all times to the extent needed by other required simulations."

Verification Guidance: *Select the first alternative if the fidelity required is replicated or partially replicated. Select the second if the fidelity is approximated or not required.*

EXAMPLES
3.7.3.4.3 Pneumatic Power System. The pneumatic power system shall be approximated. The simulation shall provide a model of the pneumatic system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification.

4.2.1.7.3.4.3 Verification of Pneumatic Power System. This requirement shall be verified by demonstration in conjunction with testing required by this specification.

3.7.3.4.4 Environmental Control System (ECS). __1__.

4.2.1.7.3.4.4 Verification of Environmental Control System (ECS). CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required ECS features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing required by this specification.

RATIONALE
This section should deal with the extent of simulation of the aircraft ECS, but not the control of conditions within simulator crew areas. These may be related by allowing the simulated ECS to actually control conditions in crew areas within the limits specified in the "Environmental Conditions" paragraph (System Specification paragraph 3.3.6).

Requirements Guidance:

1. Select one of the following (paragraph c is not appropriate if there are no enclosed crew areas):

a. "The simulated environmental control system shall provide performance identical to that of the aircraft ECS as defined by the design criteria and limited by other requirements of this specification. However, the ECS shall not actually control conditions in the crew areas."

b. "The simulated environmental control system shall provide nominal aircraft performance as defined by design criteria except that the ECS shall not actually control conditions in the crew areas."

c. "The simulated environmental control system shall provide performance identical to that of the aircraft ECS as defined by the design criteria and limited by other requirements of this specification. However, the ECS shall only control conditions in crew areas within limits defined by the "Environmental Conditions" paragraph of this specification."

Verification Guidance: *Select the first alternative if requirement a or c is selected. Select the second if requirement b is selected.*

EXAMPLES
3.7.3.4.4. Environmental Control System (ECS). The simulated environmental control system shall provide performance identical to that of the aircraft ECS as defined by the design criteria and limited by other requirements of this specification. However, the ECS shall only control conditions in crew areas within limits defined by the "Environmental Conditions" paragraph of this specification.

4.2.1.7.3.4.4. Verification of Environmental Control System (ECS). This requirement shall be verified by test. All required ECS features shall be exercised.

3.7.3.4.5 Fuel System. The fuel system shall be __1__.

4.2.1.7.3.4.5 Verification of Fuel System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required fuel system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing required by this specification.

RATIONALE
In past simulators the fuel system fidelity has generally been partially replicated or approximated as discussed below.

Requirements Guidance:

1. *Select one of the following:*

    a. *"Replicated. The simulation shall provide a complete model of the aircraft fuel system including reservoirs, pumps, tanks, weight change and distribution, flow rates, etc., as well as a complete set of interfaces with other aircraft systems."*

    b. *"Partially Replicated. The simulation shall provide a model of the aircraft fuel system including reservoirs, pumps, tanks, valves, weight change and distribution, flow rates, etc., as well as a set of interfaces with other aircraft systems that are necessary to satisfy other requirements of this specification."*

    c. *"Approximated. The simulation shall provide a model of the fuel system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification."*

    d. *"Not Required. The simulation shall assume sufficient fuel is available at all times."*

Verification Guidance: *Select the first alternative if the fidelity required is replicated or partially replicated. Select the second if the fidelity is approximated or not required.*

EXAMPLES
3.7.3.4.5 Fuel System. The fuel system shall be approximated. The simulation shall provide a model of the fuel system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification.

4.2.1.7.3.4.5 Verification of Fuel System This requirement shall be verified by demonstration in conjunction with testing required by this specification.

3.7.3.4.6 Auxiliary Power System. The aircraft auxiliary power system shall be __1__.

4.2.1.7.3.4.6 Verification of Auxiliary Power System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required fuel system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing required by this specification.

RATIONALE
Typical functions of the Aircraft auxiliary power system are:

a. *Aircraft main engine starting (ground and in-flight).*
b. *Environmental conditioning power (ground and in-flight).*
c. *Self-sufficient ground maintenance power.*
d. *Essential and non-essential power for operation of the air vehicle.*
e. *Engine motoring.*
f. *Emergency power.*

Requirements Guidance:

1. *Select one of the following:*

a. *"Replicated. The simulation shall provide a complete model of the auxiliary power system, as well as a complete set of interfaces with other aircraft systems. Transient and load effects shall be modeled."*

b. *"Approximated. The simulation shall provide a model of the auxiliary power system sufficient to interface with other aircraft systems to the extent necessary to provide the performance required by this specification."*

c. *"Not Required. The simulation shall assume the auxiliary power system is available as necessary to meet other specification requirements."*

Verification Guidance: *Select the first alternative if the fidelity required is replicated. Select the second if the fidelity is approximated or not required.*

3.7.3.4.7 Landing Gear System. The landing gear system shall be __1__.

4.2.1.7.3.4.7 Verification of Landing Gear System. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All required landing gear system features shall be exercised.

-OR-

This requirement shall be verified by demonstration in conjunction with testing required by this specification.

RATIONALE

Requirements Guidance:

1. Select one of the following:

a. "Replicated. The simulation shall provide a complete transient and steady state model of landing gear operation, including effects on all other simulated systems."

c. "Approximated. The simulation shall provide a model of landing gear operation sufficient to meet all other requirements of this specification."

d. "Not Required. The simulation shall assume the landing gear is always up."

Verification Guidance: *Select the first alternative if the fidelity required is replicated. Select the second if the fidelity is approximated or not required.*

EXAMPLES
3.7.3.4.7 Landing Gear System. The landing gear system shall be approximated. The simulation shall provide a model of landing gear operation sufficient to meet all other requirements of this specification.

4.2.1.7.3.4.7 Verification of Landing Gear System. This requirement shall be verified by demonstration in conjunction with testing required by this specification.

3.7.3.4.8 Fire Protection Systems. __1__.

4.2.1.7.3.4.8 Verification of Fire Protection Systems. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

This requirement shall be verified by test. All features of the system shall be exercised.

-OR-

Verification of this requirement is not applicable.

RATIONALE

Requirements Guidance:

1. Select one of the following (further tailoring may be required depending on malfunction definition and the particulars of the aircraft fire protection system):

a. "Aircraft fire protection systems shall be replicated in all normal and emergency modes of operation. The system shall interact with required malfunctions and crew procedures to detect and suppress overheat and fire conditions under all conditions defined by the design criteria."

b. "Simulation of the aircraft fire protection systems is not required."

Verification Guidance: *Select the first alternative if simulation of fire protection system modes is required -- verify by demonstration if appropriate for a tailored requirement. Otherwise select the second alternative.*

Process Guidance: *Definition of this paragraph may need to be deferred until after contract award. In this case, an appropriate task to update this specification should be included in the SOW.*

3.7.3.4.9 Aerial Delivery System (ADS). SELECT ONE OF THE FOLLOWING:

Not Applicable.

-OR-

The steady state and transient weight and balance effects on all aspects of simulated aircraft performance shall be represented for the following cargo loads and drops:

__1__. __2__.

4.2.1.7.3.4.9 Verification of Aerial Delivery System (ADS). CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. The test shall verify the weight and balance effects of cargo loads and drops. __3__.

RATIONALE
Aerial Delivery Systems have received limited attention on previous simulators. Loadmaster training has not been integrated with any previous trainers, except for the C-17 Weapons System Trainer that incorporates a loadmaster station and controls. Simulations have typically concentrated on pilot, copilot, and navigator procedures, and the aerodynamic effects of cargo loads and drops.

Requirements Guidance: *Select the first alternative if the aircraft has no aerial delivery system, or if there is no simulation requirement.*

1. *Identify the Loads to be represented.*

2. *Identify requirements to simulate the loadmaster station.*

Verification Guidance:

3. *Identify requirements for test of the loadmaster station.*

EXAMPLES
3.7.3.4.9 Aerial Delivery System (ADS).The steady state and transient weight and balance effects on all aspects of simulated aircraft performance shall be represented for the following cargo loads and drops:

a. M1A2 Tank.

b. Black Hawk Helicopter.

c. Standard Pallets.

d. 100 paratroopers.

All controls at the loadmaster station shall function in all normal and abnormal modes as defined by the design criteria.

4.2.1.7.3.4.9 Verification of Aerial Delivery System (ADS). This requirement shall be verified by test. The test shall verify the weight and balance effects of cargo loads and drops. This test shall also fully execute loadmaster controls.

NOTE: With the above requirement, paragraph 3.2.2 "Physical Characteristics" should specify the location and extent of the Loadmaster Station. It may also be appropriate to specify Entities representing dropped cargo.

3.7.3.5 Air Vehicle Health Management Systems. Not required.

-OR-

Air Vehicle health management systems shall:

(1) a. Provide normal indications during self test, and ground and in-flight operation.

(1) b. Provide proper indications for required malfunctions.

(2) Other system features are not required.

4.2.1.7.3.5 Verification of Air Vehicle Health Management Systems. CHOOSE ONE OF THE TWO FOLLOWING ALTERNATIVES:

Verification of this requirement is not applicable.

-OR-

This requirement shall be verified by test. (3) Indications of each required malfunction, self-test indications, and normal operation shall be verified. Malfunction indications shall be verified in conjunction with malfunction testing required herein.

RATIONALE
Health management systems include both warning and caution lights, as well as computer-based integrated diagnostic systems. If the simulator is training a full mission or various emergencies, it is appropriate to provide the indications required for malfunctions as well as self test and normal indications. If emergency training is not required, then just normal indications may be appropriate. In some cases, no health management system simulation may be required.

Requirements Guidance: *Select the requirement*

1. *Delete a or b as appropriate. Modify a and b to be consistent with the actual air vehicle.*

2. *If the aircraft system provides for post mission analysis, this sentence should be included. Otherwise, delete this sentence.*

Verification Guidance: *Select the applicable statement.*

3. *Modify the text following (3) to be consistent with the tailored requirement.*

EXAMPLES
For a simulator with no malfunctions:

3.7.3.5 Air Vehicle Health Management Systems. Air Vehicle health management systems shall provide normal indications during self test, and ground and in-flight operation. Other system features are not required.

4.2.1.7.3.5 Verification of Air Vehicle Health Management Systems. This requirement shall be verified by test. Self-test indications and normal operation shall be verified.

3.7.3.6 Air Vehicle Crew Systems.

4.2.1.7.3.6 Verification of Air Vehicle Crew Systems. Verification of this requirement is not applicable.

RATIONALE
This is a lead-in paragraph only.

3.7.3.6.1 Instrumentation, Controls and Displays. The fidelity of the crew station instrumentation, controls and displays shall be in accordance with the subparagraphs of this paragraph.

a. Unless otherwise specified, the following definitions shall apply for the minimum required levels of fidelity:

(1) Replicated -- Shall be in the correct location, and have the appearance and feel of the aircraft equipment as defined by the approved design criteria (but need not be aircraft equipment). Shall be interfaced with the simulator computational system such that the computer can identify the state of the controls, and drive the instrumentation and displays in accordance with this specification.

(2) Depicted -- Need not be in the exact location, nor have the appearance or feel of the aircraft equipment. Shall be interfaced with the simulator computational system such that the computer can identify the state of the controls, and drive the instrumentation and displays in accordance with this specification.

(3) Inert -- Shall be in the correct location, and have the appearance and feel of the aircraft equipment as defined by the approved design criteria (but need not be aircraft equipment). Need not be interfaced with the simulator computational system.

(4) Pictorial -- May be a static picture of the aircraft equipment, but shall be of the size and in the location defined by the approved design criteria.

(5) Not Required -- No representation of the aircraft equipment is required.

b. Simulated systems shall operate interactively with replicated and depicted controls, and respond in accordance with the requirements of this specification. Simulated systems shall operate as if any inert, pictorial, or not-required controls were in the nominal state defined in accordance with this specification or the approved design criteria.

4.2.1.7.3.6.1 Verification of Instrumentation, Controls and Displays. Verification of this requirement is not applicable.

RATIONALE
This is an introductory paragraph to the section which defines the required levels of fidelity for all crew station instrumentation, controls and displays.

Requirements Guidance:
Requirements for functional operation of the various aircraft subsystems are not included here, but rather in the paragraph dealing with the simulation requirements for the relevant subsystem. WITH THE

EXCEPTION OF THE FLIGHT CONTROLS (which cannot generally be specified independently of components of air vehicle simulation, such as hinge moments or control surface movements), THE REQUIREMENTS OF THIS SECTION DEAL STRICTLY WITH THE FIDELITY OF THE INSTRUMENTS, CONTROLS AND DISPLAYS. If an instrument, control or display is required to support the functional simulation of its associated subsystem, it must be interfaced to the computer (i.e., either the 'replicated' or 'depicted' level of fidelity apply). If an instrument, control or display must be rendered as a full three-dimensional representation of the aircraft equipment (e.g., to provide tactual cues), it must be either 'replicated' or 'inert'. If it is sufficient to represent aircraft equipment on a flat-panel or CRT display (which could include a crewmember control interface such as a touch screen), a 'depicted' level of fidelity would be appropriate. Where no functional simulation of the associated subsystem is required (nor expected to be required), the appropriate level of fidelity would be 'pictorial' or 'not required'.

There may be controls which are defined as 'inert', 'pictorial', or 'not required' which affect the response of some simulated systems. In these instances, decisions must be made -- and documented -- regarding the state of the control's input to be assumed while simulating the system. There are two recommended alternatives for documenting these decisions: (a) the assumptions can be included as a part of the requirement for the simulation of the associated system, or (b) the design solution can be deferred and the assumptions included in this specification at a later date (in which case the Statement of Work should define a process for accomplishing this action).

Either static or dynamic control states may be assumed. The following are two examples which illustrate situations where one or the other might apply.

a. Circuit breaker panels might be pictorial representations in some lesser-fidelity flight simulators. The "Electrical Power System" simulation requirement might define the assumed control state to be static for each circuit breaker (either closed or open).

b. Should the flight control pedals be designated as inert, assumption of a static state for the control's input would probably not be satisfactory. More likely, pedal commands to maintain coordinated turns in flight -- an assumption of a dynamic controller state -- would be appropriate.

Verification Guidance:
Verification requirements are to be included with the subparagraphs of this section. Except for the flight controls, verification will typically be by inspection or demonstration. Functional interfaces will normally be tested under the paragraphs dealing with the functional simulation of the associated subsystems.

Process Guidance:
If assumptions regarding a non-interfaced control's inputs are left "to be determined" (an alternative discussed above), a process needs to be defined which will accomplish their determination and subsequent documentation as a part of the approved design criteria.

3.7.3.6.1.1 Flight Controls. The ___1___ flight controls shall be ____2____. Gearing (control surface movement versus cockpit flight control movement) shall be in accordance with the approved design criteria. Simulated force feedback at the flight controls shall be ___3___. ___4___ shall be ___5___.

4.2.1.7.3.6.1.1 Verification of Flight Controls. This requirement shall be verified by inspection ___6___ and test. Inspection shall verify compliance with appearance and location requirements of the flight controls and controls located upon these flight controls. The tolerances specified in this paragraph shall also apply to relevant dynamic tests conducted in accordance with paragraph 4.2.1.7.3.

Mechanical Characteristics:
Tests shall verify that the mechanical characteristics of the flight controls fall within the tolerance limits specified below for each primary control loading axis with full uninterrupted stop-to-stop control sweeps. Responses shall be measured at the controls. A full control sweep shall be defined as movement of the controller from neutral to a stop, then to the opposite stop, then back to the neutral position. Tests shall include responses to full control sweeps ___7___. Measured responses shall correspond to those of the aircraft in ___8___ configurations, for the following flight conditions: ___9___.

AXIS	FREEPLAY	FORCE	BREAKOUT PLUS FRICTION	CONTROL ENVELOPE
Longitudinal	___ inch or __%	___ pounds or __%	___ pounds or __%	___ inch or __%
Lateral	___ inch or __%	___ pounds or __%	___ pounds or __%	___ inch or __%
Collective	___ inch or __%	___ pounds or __%	___ pounds or __%	___ inch or __%
Pedal	___ inch or __%	___ pounds or __%	___ pounds or __%	___ inch or __%

Tests shall verify that gearing falls within ___ degree or __% of the approved design criteria.

Trim Rates:
Tests shall verify trim rates are in accordance with the approved design criteria.

Trim Release Stick Jump (Rotary-wing Aircraft Only):
Demonstration shall verify trim release stick jump.

Control Free Response:
Tests shall verify that the free response of the controls can adequately simulate that of the aircraft for each primary control loading axis. For underdamped responses, the number of overshoots greater than 5% of the total initial displacement shall be the same as the aircraft, as specified in the approved design criteria; the time to first peak shall be within __10__ milliseconds of the approved design criteria. For overdamped and critically damped responses (i.e., no overshoot), the time to reach 90 % of the final value shall be within __11__ milliseconds of the approved design criteria.

Force-loop Frequency Response:
Tests shall verify that the control-fixed, closed-loop force gain and phase shift satisfy the requirement. Force gain shall be defined as twenty times the logarithm of the ratio of the force transducer output signal to the force command input signal to the control loader. Phase shift shall be defined as the phase of the force transducer output relative to the force command input.

RATIONALE

Requirements Guidance:
Blank (1) should identify the flight controls to be included, and should be tailored to the application. This would typically be "wheel, column, and pedal" for a classical transport aircraft, "stick and pedal" for a classical tactical aircraft, or "cyclic, collective, and pedal" for a rotary-wing aircraft; superaugmented, fly-by-wire aircraft might have something like a "right side-arm controller and pedal". In lower fidelity applications, all flight controls (e.g., pedal) may not be required.

Blank (2) should state the required level of fidelity for the flight controls, which would typically be "replicated, and have displacement in accordance with the approved design criteria." For a very low fidelity device (where a simple joystick might suffice), blank (2) would be "depicted" but would include any additional qualifications, such as "depicted, three-dimensional joystick controls."

Blank (3) should define the force simulation required, in accordance with the following guidance:

FULL-FIDELITY SIMULATION OF TRADITIONAL MECHANICAL FLIGHT CONTROL SYSTEMS: in this case, high-quality force feedback is required. Put the following into blank (3): "in accordance with this

specification. Each axis of the flight controls shall have the following force-loop frequency response. The control-fixed, closed-loop force gain shall be between +0 and - 0.5 dB at 0.1 Hz, and decrease monotonically to no less than -3 dB at 50 Hz; the corresponding phase shift shall be between +0 and -3 degrees from 0.1 to 5 Hz, and between +0 and -100 degrees from 5 to 50 Hz."

NOTE REGARDING THE FORCE-LOOP FREQUENCY RESPONSE REQUIREMENT:
Control force (pressure on the hand) is a predominant tactual cue; the human hand is extremely sensitive to small force fluctuations at frequencies in excess of 500 Hz. The control-fixed, force bandwidth of the system is a critical indicator of the system's capability to provide acceptable cues. The force-loop frequency response of a full-fidelity simulation of a traditional mechanical flight control system should exhibit a bandwidth of at least 50 Hz without resonant peaks (which this frequency response requirement is intended to capture). If fidelity requirements demand even greater force bandwidth, larger values (e.g., 100 Hz) can be substituted for the 50 Hz values above without impacting the remainder of the recommended wording.

LESSER FIDELITY SIMULATORS: This might apply for devices intended for uses such as procedural refresher training of mission-qualified pilots where the emphasis is on 'switchology' and use of equipment, rather than on controlling the aircraft. If it has been determined that full-fidelity force-feedback is not required, put the following into blank (3): "representative of the aircraft force feedback, but need not provide full tactual fidelity. Force feedback shall be in accordance with the approved design criteria." In addition, be as specific as possible about the scope of tactual cuing requirements; e.g., it may be made clear that a passive simulation will suffice (see EXAMPLES). Since "representative of the aircraft force feedback" is a very subjective term, it is recommended that the force-feel simulation be prototyped and demonstrated with the intended user; a force-feel transfer characteristic which is acceptable to the user should then be documented and made part of the approved design criteria.

FLY-BY-WIRE CONTROL SYSTEMS: In this case, there is no mechanical linkage between the pilot and control surfaces. It is sufficient that simulator controller force and displacement match that of the aircraft controller. In blank (3), place "in accordance with the approved design criteria."

CAUTION: Be aware that the computational system will not be able to automatically position the controls (for purposes such as 'playback' or 'auto trim') with lesser-fidelity representations, unless computer control of the controllers' position is explicitly added as a requirement. Computer control of the controllers' position is inherent in a full fidelity simulation of a mechanical flight control system, however, since this requires that the computational system provide some form of force and position feedback.

Blanks (4) and (5) are intended to capture the fidelity requirements of the switches, buttons, and any other controls located on the flight controls. If full simulation of all controls is required, put "All controls located on the flight controls" into blank (4) and "replicated" into blank (5). For lesser, selective fidelity, enumerate the required level of fidelity for each of the controls located on the flight controls (see EXAMPLES).

Verification Guidance:
The "Verification of Flight Controls" paragraph is written for a full-fidelity simulation of a traditional mechanical flight control system, and should be tailored downward where requirements call for lesser control loading fidelity. Tests or demonstrations should be retained for any quantitative requirements such as gearing, control envelope, and control free response. Blank (6) is provided as a reminder to add ", demonstration" if appropriate.

Blank (7) is intended for full-fidelity applications. Some control loaders may not have the dynamic range to respond with sufficient torque (i.e., force feedback) at all control velocities, so tests at both low and high velocities are necessary to assure that the loader is adjusted properly for the simulator under test. For full-fidelity applications put "having periods of approximately 100 seconds and 4 seconds" into blank (7). For lesser fidelity applications, skip blank (7).

In blank (8), specify "taxi, takeoff, landing, and in-flight" or whatever is appropriate to the operating envelope for this simulator. The range of test conditions specified in blank (9) should be consistent with the approved design criteria and consist of a sufficient sample to prove compliance for effects such as those due to changes in aerodynamic forces in flight (e.g., dynamic-pressure-feel system operation, control surface blowdown) and during ground operations (including taxi, takeoff, and landing), for all relevant normal and abnormal conditions. For lesser fidelity requirements where aerodynamic conditions or aircraft configuration has no effect on controller response, delete the sentence containing blanks (8) and (9).

For typical military aircraft, the following values are suggested for the Mechanical Characteristics Tolerances Table ("Collective" applies to rotary-wing aircraft only):

AXIS	*FREEPLAY*	*FORCE*	*BREAKOUT PLUS FRICTION*	*CONTROL ENVELOPE*
Longitudinal & Lateral & Collective	*0.1 inch or 10%*	*0.5 pounds or 10%*	*0.5 pounds or 5%*	*0.5 inch or 5%*
Pedal	*0.1 inch or 10%*	*2.0 pounds or 10%*	*0.5 pounds or 5%*	*0.25 inch or 5%*

Gearing: Tolerance of 0.5 degree or 5%.

Trim Rates: The aircraft maintenance manual may be the best approved design criteria, if a current version will be available when the test is conducted.

Trim Release Stick Jump: This is typically subject to pilot evaluation.

Control Free Response: The suggested tolerance to be placed in blanks (10) and (11) is 100 milliseconds. One important aspect of the free response test is that it demonstrates that the effective inertia of the simulator control linkage is sufficiently low that it does not inhibit adjustments for proper simulation of controller natural frequency.

Force-loop Frequency Response: This verification requirement applies if the frequency response requirement was included in blank (3) as part of the force simulation requirement.

Note that some of the Federal Aviation Administration (FAA) AC-120-40B tolerances for certification of simulators for commercial aircraft are looser than those recommended above. These FAA tolerances are appropriate for commercial transport-class aircraft -- but certainly not for military fighter-class aircraft, where 7.0 pounds applied force may be all that is required for stop-to-stop movement of the stick. Tolerances specified should be a function of aircraft class and the characteristics of the specific control system being simulated. For the sake of consistency across simulators, tolerances should be selected from those recommended above or the FAA AC-120-40B set whenever practical. Samples of FAA tolerances are provided below for convenient reference; for details regarding specific application, refer to AC-120-40B.

AXIS	*FORCE*	*BREAKOUT*
Longitudinal	*5.0 pounds or 10 %*	*2.0 pounds*
Lateral	*3.0 pounds or 10 %*	*3.0 pounds*
Pedal	*5.0 pounds or 10 %*	*5.0 pounds*

Gearing: Tolerances of one to three degrees, depending on control surface.

Process Guidance:
If a level of fidelity "representative of the aircraft force feedback" is specified, a process should be defined which results in: (a) the force-feel simulation being prototyped and demonstrated with the user, and (b) the documentation of the acceptable force-feel transfer characteristic, and its incorporation into the approved design criteria.

EXAMPLES
Example 1. Where a lesser-fidelity device is being acquired for supporting practice of highly procedural tasks, substantial cost savings might be realized by reducing the fidelity required of the force-feel system. In the following example, no active pedal controls are required (although the pedals are to be physically represented and adjustable). Further, force feedback need only be representative and may be accomplished using passive components. No computer-driven movement of the controls is required, and fidelity of the controls located on the stick is selectively matched to the training/practice objectives which the device is intended to support.

3.7.3.6.1.1 Flight Controls. The stick flight control shall be replicated, and have displacement in accordance with the approved design criteria. The pedal flight control shall be inert and need not pivot, but shall be adjustable fore and aft (using the Rudder Pedal Adjustment on the Control Pedestal) over the full range specified in the approved design criteria. Gearing (control surface movement versus cockpit flight control movement) shall be in accordance with the approved design criteria. Simulated force feedback at the flight controls shall be representative of the aircraft force feedback, but need not provide full tactual fidelity and may be realized using passive control loading devices. Force feedback shall be in accordance with the approved design criteria. The two-position gun trigger on the stick shall be inert. The following stick controls shall be replicated:

a. Four-way aircraft trim switch.
b. Weapon release button.
c. Fore/aft/down auto-acquisition switch.
d. Short Range Missile/Electro-optical (SRM/EO) button.

Example 2. The corresponding verification requirement follows. A mechanical characteristics test requirement is included to assure that performance complies with the approved design criteria (which are just representative aircraft data in this case). The tolerance for friction has been opened slightly from the value recommended in the "Verification Guidance" since this is less critical for the "representative" simulation required in this example; additional cost could be incurred in using higher precision components to better control viscous friction. Since a passive implementation (implying a spring-mass-dashpot system) is acceptable, it would not be appropriate to include test tolerances for discrete nonlinearities such as breakout forces, although -- obviously -- hard stops can be implemented and should be tested. A control-free response test requirement is included to assure that the (what should have been prototyped) system implementation and the approved design criteria are consistent.

4.2.1.7.3.6.1.1 Verification of Flight Controls. This requirement shall be verified by inspection and test. Inspection shall verify compliance with appearance and location requirements of the flight controls and controls located upon these flight controls.

Mechanical Characteristics:
Tests shall verify that the mechanical characteristics of the flight controls fall within the tolerance limits specified below for each primary control loading axis with full uninterrupted stop-to-stop control sweeps. Responses shall be measured at the controls. A full control sweep shall be defined as movement of the controller from neutral to a stop, then to the opposite stop, then back to the neutral position. Tests shall include responses to full control sweeps.

AXIS	FREEPLAY	FORCE	FRICTION	CONTROL ENVELOPE

Longitudinal & Lateral	0.1 inch or 10 %	0.5 pounds or 10 %	0.5 pounds or 10 %	0.5 inch or 5 %

Tests shall verify that gearing falls within 0.5 degree or 5% of the approved design criteria.

Trim Rates:
Tests shall verify trim rates are in accordance with the approved design criteria.

Control Free Response:
Tests shall verify that the free response of the controls can adequately simulate that of the aircraft for each primary control loading axis. The number of overshoots greater than 5% of the total initial displacement shall be as specified in the approved design criteria; the time to first peak shall be within 100 milliseconds of the approved design criteria.

3.7.3.6.1.2 Throttle Controls. The throttle controls shall be ___1___. The throttle control position ___2___ actively driven under the control of the simulator computational system. ___3___ shall be ___4___.

4.2.1.7.3.6.1.2 Verification of Throttle Controls. This requirement shall be verified by inspection and demonstration. Inspection shall verify appearance and location. Demonstration shall verify that tactual feedback from the controls ___5___ and simulator computational system interface comply with the approved design criteria.

RATIONALE

Requirements Guidance:
Blank (1) should define the minimum level of fidelity required in accordance with the definitions of paragraph 3.7.3.6.1. Include any tailoring of the requirement by expanding beyond the paragraph 3.7.3.6.1 definition here (see EXAMPLES).

Blank (2) is intended to convey whether the throttle controls need to be computer-driven (e.g., to automatically position the throttles during 'playback' or during the conduct of test procedures). Insert "shall be" or "is not required to be" in Blank (2). If fidelity requirements are such that no ambiguity is introduced, the sentence containing Blank (2) may be deleted (see EXAMPLES).

Blanks (3) and (4) are intended to capture the fidelity requirements of the switches, buttons, and any other controls located on the throttles. If full simulation of all controls is required, put "All controls located on the aircraft throttle controls" into blank (3) and "replicated" into blank (4). For lesser, selective fidelity, enumerate the required level of fidelity for each of the controls located on the throttle controls (see EXAMPLES for paragraph 3.7.3.6.1.1).

Verification Guidance:
If the throttles are to be driven under computer control, insert ", computer-controlled throttle positioning," into Blank (5); otherwise, ignore Blank (5). If aircraft-like tactual feedback is not required, amend the sentence containing Blank (5) accordingly (see EXAMPLES).

Process Guidance:

EXAMPLES
Example 1. For a device where high-fidelity tactual feedback (e.g., the feel of mechanical discrimination among the OFF, IDLE, MILITARY POWER, and AFTERBURNER positions) is required for HOTAS practice, but individual engine control is not required:

3.7.3.6.1.2 Throttle Controls. The throttle controls shall be replicated. The body of the throttle may be formed as one piece (no split throttle movement for individual engine settings is required). The throttle control position shall be actively driven under the control of the simulator computational system. All controls located on the aircraft throttle controls shall be replicated.

4.2.1.7.3.6.1.2 Verification of Throttle Controls. This requirement shall be verified by inspection and demonstration. Inspection shall verify appearance and location. Demonstration shall verify that tactual feedback from the controls, computer-controlled throttle positioning, and simulator computational system interface comply with the approved design criteria.

Example 2. For a device where HOTAS is not a concern (e.g., training strategies may be such that the trainer should not mimic the cockpit environment too closely), but a three-dimensional throttle (or perhaps airspeed -- depending upon the requirements specified under "Air Vehicle Powerplant") controller is a requirement:

3.7.3.6.1.2 Throttle Controls. The throttle controls shall be depicted using a three-dimensional control. All controls located on the aircraft throttle controls shall be depicted.

4.2.1.7.3.6.1.2 Verification of Throttle Controls. This requirement shall be verified by inspection and demonstration. Inspection shall verify appearance and location. Demonstration shall verify that simulator computational system interface complies with the approved design criteria.

3.7.3.6.1.3 Escape System Controls. All controls associated with manual initiation of the automated ejection system shall be ___1___. Performance of proper ejection procedures by a crewmember shall result in an aural cue in accordance with the approved design criteria, and shall command a halt event.

4.2.1.7.3.6.1.3 Verification of Escape System Controls. This requirement shall be verified by ____2____.

RATIONALE

Requirements Guidance:
For aircraft which are not equipped with automated escape systems, the stated requirement would be "This requirement is not applicable." Otherwise use the first sentence as it is; Blank (1) should define the minimum level of fidelity required in accordance with the definitions of paragraph 3.7.3.6.1. The second sentence reflects the traditional events associated with simulated actuation of an escape system. Consider whether the second sentence is suitable for the way in which this simulator is to be used (and consistent with the level of fidelity specified for the controls); modify or delete the second sentence accordingly.

Verification Guidance:
For aircraft which are not equipped with automated escape systems, the stated requirement would be "Verification of this requirement is not applicable." Otherwise use the recommended sentence; Blank (2) should be filled in with "inspection" or "demonstration", depending on the required level of fidelity for the controls and the need to demonstrate proper interface to the simulator's computer.

Process Guidance:
A process for determining an appropriate aural cue and documenting same in the approved design criteria needs to be established.

3.7.3.6.1.4 Crew Station Panels. All crewstation controls, displays, and instruments located on panels ___1___ shall be replicated, with the following exceptions: ___2___.

4.2.1.7.3.6.1.4 Verification of Crew Station Panels. This requirement shall be verified by inspection and demonstration. Inspection shall verify location and appearance, and demonstration shall verify computer interfaces and the feel of controls.

RATIONALE

Requirements Guidance:
For a full-fidelity simulation where all panel controls and displays must be replicated, Blank (1) would identify the crewstation panels involved (e.g., "located forward of the bulkhead separating the cockpit and passenger compartments", "located forward of a cross-section of the fuselage at the most extreme aft setting of the pilots' seats", or "forward of Station 5030 MM"). Blank (2) would include exceptions by identifying the specific controls and displays (or panels), and the levels of fidelity of those controls/displays/panels in accordance with the definitions of paragraph 3.7.3.6.1.

For a lesser-fidelity simulation, a different -- far more detailed -- approach is needed. Care must be taken to assure the required fidelity of each control, display, and instrument is identified. Simulator engineers, subject matter experts, and any other appropriate user representatives need to assure that the fidelity requirements are defined in detail, and are consistent with the intended training, practice, or mission rehearsal objectives for the device. It is recommended that each panel be allocated a subparagraph, and that the fidelity of each control, display, and/or instrument on that panel be specified (see EXAMPLES). All instrumentation, controls and displays which are not located on the flight controls, throttles, or escape system must be accounted for here. These could include a heads-up display (HUD), standby magnetic compass, etc. Panels could be segregated by location, e.g. according to those located on the flight control pedestal, the main instrument panel, left-side and right-side console panels, and overhead panels; panels for all relevant crew member positions (e.g., Flight Engineer, Navigator, etc) must be included.

Verification Guidance:
Verification of this requirement consists of assuring appropriate appearance, control feel, and a computer interface sufficient to identify control positions and drive displays and instruments. The proper response of the underlying systems will be verified through verification of the corresponding system simulations. Demonstrations of computer interface at this point should be limited, since most interfaces will be verified exhaustively in verifying proper simulation of air vehicle system response.

EXAMPLES
The following provides one example for organizing the requirement for a lesser-fidelity simulation. Here the fidelity of each control and display would be selectively tailored by considering the objectives the simulator is to support:

3.7.3.6.1.4 Crew Station Panels. The minimum level of fidelity for crew station instrumentation, controls and displays shall be as specified in the following subparagraphs.

3.7.3.6.1.4.1 Flight Control Pedestal.

3.7.3.6.1.4.1.1 Flap Control Panel. All controls shall be depicted.

3.7.3.6.1.4.1.2 Trim Control Panel. All controls shall be depicted.

3.7.3.6.1.4.1.3 Elevator Tab Power Switch. This switch shall be depicted.

3.7.3.6.1.4.1.4 Engine Condition Levers. These controls shall be replicated.

3.7.3.6.1.4.1.5 Temperature Datum Control Valve Switch Panel. This panel shall be pictorial.

3.7.3.6.1.4.1.6 Etcetera, etcetera.

3.7.3.6.1.4.2 Main Instrument Panel.

3.7.3.6.1.4.2.1 Electronic Fuel Correction Panel. All displays shall be pictorial.

3.7.3.6.1.4.2.2 Engine Instruments Panel. All displays shall be depicted.

3.7.3.6.1.4.2.3 Master Caution Panel. All controls and displays shall be depicted.

3.7.3.6.1.4.2.4 Etcetera, etcetera.

3.7.3.6.1.4.3 Heads-up Display (HUD). This display shall be depicted. HUD imagery shall be placed at the same focal plane as out-the-window imagery.

3.7.3.6.1.4.4 Magnetic Compass. This instrument shall be replicated.

3.7.3.6.1.4.5 Left-side Console.

3.7.3.6.1.4.5.1 Radar Control Panel. All controls shall be replicated.

3.7.3.6.1.4.5.2 Communications Control Panel. The CRYPTO MODE, INTER-OUTER COMMUNICATION, and COMPASS switches shall be inert. All other controls shall be replicated.

3.7.3.6.1.4.5.3 Etcetera, etcetera.

3.7.3.6.1.4.6 Etcetera, etcetera.

3.7.3.6.2 Lighting.

4.2.1.7.3.6.2 Verification of Lighting. Verification of this requirement is not applicable.

RATIONALE
This is a title-only, lead-in paragraph.

3.7.3.6.2.1 Interior Lighting. The crew station lighting system, including lenses, covers, and utility lights, shall be simulated. Lighting intensity levels, appearance, and control shall be in accordance with the approved design criteria.

4.2.1.7.3.6.2.1 Verification of Interior Lighting. This requirement shall be verified by demonstration.

RATIONALE

Requirements Guidance:
For the typical application, the wording proposed for the requirement should suffice. There will be instances, however, when only partial simulation or no crew station lighting is required (e.g., in an open-cockpit procedures trainer where ambient room lighting is available, and most or all of the cockpit panels are depicted, inert, or lesser fidelity). In these instances, state what is required -- do not use the proposed requirement wording.

Verification Guidance:
Demonstration of the crew station lighting system simulation to subject matter experts should suffice for the typical simulator. For lesser fidelity requirements, no verification may be needed; in this case, replace the proposed wording with "This requirement is not applicable."

3.7.3.6.2.2 Exterior Lighting. __1__ lighting system(s) shall be simulated. Lighting intensity levels, appearance and control shall be in accordance with the approved design criteria.

4.2.1.7.3.6.2.2 Verification of Exterior Lighting. This requirement shall be verified by demonstration.

RATIONALE

Requirements Guidance:
In blank (1), insert the exterior lighting to be simulated. Simulation of landing and taxi lights is required for Level B, C, and D airplane and helicopter simulators. Other exterior lighting simulation (e.g., navigation, anticollision, beacon, formation, aerial refueling, tail flood, or wing inspection lights) may be needed to satisfy ownship platform signature fidelity requirements in multi-station or interactive simulations. If simulation of exterior lighting is not required, delete this subparagraph.

Verification Guidance:
Demonstration of the exterior lighting system simulation to subject matter experts should suffice.

EXAMPLES
A primary training aircraft with no combat simulation. The simulator is to include multiple stations that can operate interactively for formation flight training.

3.7.3.6.2.2 Exterior Lighting. Landing, taxi, navigation, anticollision, beacon, and formation lighting systems shall be simulated. Lighting intensity levels, appearance and control shall be in accordance with the approved design criteria.

3.7.3.6.3 Personal Equipment and Systems. Except as required by the subparagraphs below, personal equipment such as the oxygen mask and flight helmet shall not be provided. ___1___

4.2.1.7.3.6.3 Verification of Personal Equipment and Systems. Verification of this requirement is not applicable.

RATIONALE
This is a lead-in paragraph. Normally personal items issued to aircrew members, such as helmets, oxygen masks and anti-g suits, are brought to the simulator by the crewmember.

Requirements Guidance:
Normally provisions must be available in the simulator for the aircrew to connect their communications and other equipment to the aircraft system -- for those aircraft systems to be simulated. In this case, fill in blank (1) with "Provisions shall be made for the connection and function of crewmembers' communication and other personal equipment in accordance with the subparagraphs of this paragraph."

If some (or all) of the personal equipment systems do not need to be simulated (as may be the case in an open-cockpit procedures training device), delete or tailor blank (1) to specifically include only those systems which are to be simulated.

There may sometimes be a requirement for spare personal-type items to be on hand with the simulator, or simulated personal-type items may sometimes be simulator-specific (e.g., simulated Night Vision Goggles might be fabricated to include an internal out-the-window visual display system). Should such be the case, include the requirement for the item(s) to be furnished with the simulator in the appropriate subparagraph(s).

3.7.3.6.3.1 Life Support System. ___1___.

4.2.1.7.3.6.3.1 Verification of Life Support System. Verification of this requirement is not applicable.

RATIONALE
This is a lead-in paragraph.

Requirements Guidance:
If simulation of aircraft life support systems is required, place "The life support system simulation shall be simulated in accordance with the following subparagraphs" in blank (1). Otherwise, place "This requirement is not applicable" in blank (1) and delete the subparagraphs.

If some of the subparagraphs do not apply, state "This requirement is not applicable" in the appropriate requirements subparagraph. If life support system simulation is required but does not map into the proposed subparagraphs well, tailor the quantity and titles of the subparagraphs to better reflect what is required.

Verification Guidance:
For any retained, nonapplicable subparagraph, state "Verification of this requirement is not applicable".

3.7.3.6.3.1.1 Oxygen System. The oxygen system shall be simulated to function as in the aircraft, in accordance with the approved design criteria. Breathing air which is dry, free of oil and other contaminants, and compatible with standard aircrew-issued equipment shall be used in lieu of oxygen. The capability to sample the breathing air shall be provided.

4.2.1.7.3.6.3.1.1 Verification of Oxygen System. This requirement shall be verified by demonstration and test. Demonstration shall verify the functionality of the oxygen system simulation and the capability to sample the breathing air. Air sampling tests of breathing the air shall verify that the air is dry, free of contaminants and compatible with standard aircrew-issued equipment.

RATIONALE
If the simulation of the aircraft oxygen system is required, the proposed wording should suffice. The breathing air needs to be dry and free of oil and other contaminants to prevent contamination of the aircrew's oxygen masks, as well as for reasons of safety. A permanent means of sampling the air is required to support routine maintenance tests of the breathing air.

3.7.3.6.3.1.2 High Acceleration Protection. The following high acceleration protection systems shall be simulated in accordance with the subparagraphs of this paragraph.

a. ___1___
b. ___1___
.
.
.
n. ___1___

4.2.1.7.3.6.3.1.2 Verification of High Acceleration Protection. Verification of this requirement is not applicable.

RATIONALE
This paragraph and its subparagraphs are intended to include all requirements regarding simulation of high acceleration protection systems, with the exception of body-positioning seat systems which are more appropriately covered under "Seating".

Requirements Guidance:
The specific high acceleration protection systems to be simulated should be put into blanks (1). These could include an anti-g suit system, a positive breathing pressure system, or other high acceleration protection systems such as equipment for the detection of the onset of acceleration-induced loss of consciousness and the automatic recovery of the aircraft upon pilot incapacitation.

3.7.3.6.3.1.2.1 Anti-g Suit System. With the exception of anti-g suit pressurization, the anti-g suit system shall be simulated to function as in the aircraft -- in accordance with the approved design criteria. The simulated anti-g suit system shall provide the ___1___ with anti-g suit pressure cues, using a pressurization schedule in accordance with this paragraph. The anti-g suit pressurization schedule shall range from zero psi (atmospheric pressure) to a maximum of ___2___ psi. Fail-safe means shall be provided to assure that the maximum pressurization does not exceed this specified maximum value. The "pressure onset" (g-intercept at zero psi) shall be adjustable from ___3___ to ___4___ g units. The "slope" of the pressure curve (psi/g) shall be adjustable from ___5___ to ___6___ psi/g. The anti-g suit shall respond to a full-range commanded step change in pressure by reaching 63 percent of its final value within ___7___ seconds for inflation and ___8___ seconds for exhaust. The anti-g suit shall be pressurized to a steady-state level corresponding to a one-g state when a "freeze" is commanded. Otherwise, the steady-state suit pressure shall be in accordance with the following schedule.

If aircraft acceleration is less than or equal to Pressure Onset:
    Suit Pressure (psi) = 0

If aircraft acceleration greater than Pressure Onset:
    Suit Pressure (psi) = (Slope) x [(G-units) - (Pressure Onset)], subject to the maximum pressure limit.

4.2.1.7.3.6.3.1.2.1 Verification of Anti-g Suit System. This requirement shall be verified by ___9___. Inspection shall verify compliance with appearance and location requirements of the aircraft-mounted anti-g suit components. Demonstration shall verify the functionality of the anti-g suit system.

Pressure transducer(s) placed in the anti-g suit air line(s) shall be used to instrument the anti-g suit system for test. Tests shall verify compliance with the steady-state pressurization schedule within ___10___ psi or ___11___ percent over the full specified pressure range, and shall verify that the "pressure onset" and "slope(s)" are adjustable over their specified ranges. Test shall verify that a "freeze" command results in suit pressure returning to that level corresponding to one g-unit. Apply a square wave (with a period at least ten times the larger of the two specified inflation-exhaust times and an amplitude corresponding to a full-range pressure change) to the anti-g suit system input, and verify that suit pressure reaches 63 percent of its final value within the times specified for both inflation and exhaust.

Inspection and analysis of vendor drawings and control mechanisms, in conjunction with hardware tests, shall verify that the suit(s) cannot be pressurized beyond the specified maximum.

RATIONALE
Anti-g suit pressurization has been an effective (in that a pilot can learn to relate inflation cues to g-loading, and maintain g-loads on the aircraft without looking at the instruments), and fairly cheap method for providing sustained, high-g cues. However safety concerns have arisen regarding safe pressurization schedules, and incidents of injury induced by anti-g suit simulation have been reported.

Requirements Guidance:
If actual anti-g suit pressurization is not required, delete all but the first sentence.

Blank (1) should specify the aircrew positions for which anti-g suit pressure cues are to be simulated. In a multiple-place aircraft, there may be little benefit to fully simulating these systems for crewmembers

who are not piloting the aircraft (although there may be training benefit in providing connections and functioning controls and displays for all crewmembers).

Blank (2) should specify the maximum permissible pressure. Pressures used in an actual high-g environment can be uncomfortable -- or even dangerous -- in a one-g environment, since the suit is not counteracting an actual pooling of blood in the lower extremities. In past simulators, the maximum pressure has typically been specified at 7 psi. This value has since been challenged as being too high, and maximum values of 1 to 3 psi have been recommended. A Safety Engineer should be consulted regarding current policy.

Various users have had different preferences regarding the "onset" and "slope" of the suit pressurization schedule. Some users have, in fact, found it useful to set these such that there is a residual pressurization at the simulated one-g level; this has been done so that negative g-loading cues could be provided. Because of these varying preferences, a means to permit adjustment of these parameters has been required. Typically pressure "onset" may be adjustable over a range of 0 to 2 g-units. The "slope" has been adjustable over a range of 0.5 to 1.5 psi/g on systems with a maximum pressure of 7 psi; for systems with lower maximum pressures, a range of 0.1 to 1.5 psi/g would serve to compensate the lower end for the lower operating pressure. Specify the required pressure onset range in blanks (3) and (4), and the required slope in blanks (5) and (6).

Blanks (7) and (8) define the effective time constants for inflation and deflation rates, respectively. Values of 1.2 seconds for inflation and 0.65 seconds for exhaust have been found satisfactory in the past. Enhancements (such as a subatmospheric-pressure sink) may be required to obtain this deflation rate.

Verification Guidance:
If actual g-suit pressurization is not required, delete all but the first paragraph and place "inspection and demonstration" in blank (9).

If g-suit pressurization is required, place "inspection, analysis, demonstration, and test" in blank (9). Blanks (10) and (11) specify the tolerance for compliance with the required steady-state pressurization schedule. Since the crewmember(s) will be more sensitive to inflation-deflation changes than to steady-state pressures, this tolerance need not be overly restrictive; tolerance values on the order of 0.1 psi for blank (10) and 20 percent for blank (11) would be reasonable.

Process Guidance:
Since there are open safety and cuing effectiveness issues regarding pressurization schedules, a process should be defined which results in: (1) candidate pressure schedules being prototyped and demonstrated with the user, and (2) documentation of acceptable pressure schedules, and their incorporation into the approved design criteria. Since there are safety issues, this process must involve Safety Engineering. Armstrong Laboratory support may be solicited regarding safety concerns.

3.7.3.6.3.1.2.2 Positive Pressure Breathing System. With the exception of jerkin bladder and breathing air pressurization and mask tightening, the simulated positive pressure breathing system shall be simulated to function as in the aircraft -- in accordance with the approved design criteria. The simulated positive pressure breathing system shall provide the ___1___ with pressure and mask tightening cues, using a pressurization schedule in accordance with this paragraph. The breathing system pressurization schedule shall range from zero psi (atmospheric pressure) to a maximum of ___2___ psi. Fail-safe means shall be provided to assure that the maximum pressurization does not exceed this specified maximum value. The "pressure onset" (g-intercept at zero psi) shall be adjustable from ___3___ to ___4___ g units. The "slope" of the pressure curve (psi/g) shall be adjustable from ___5___ to ___6___ psi/g. The human-mounted components of the positive pressure breathing system shall respond to a full-range commanded step change in pressure by reaching 63 percent of its final value within ___7___ seconds for inflation and ___8___ seconds for exhaust. These components shall be

pressurized to a steady-state level corresponding to a one-g state when a "freeze" is commanded. Otherwise, the steady-state pressure shall be in accordance with the following schedule.

If aircraft acceleration is less than or equal to Pressure Onset:
Pressure (psi) = 0

If aircraft acceleration greater than Pressure Onset:
Pressure (psi) = (Slope) x [(G-units) - (Pressure Onset)], subject to the maximum pressure limit.

4.2.1.7.3.6.3.1.2.2 Verification of Positive Pressure Breathing System. This requirement shall be verified by ___9___. Inspection shall verify compliance with appearance and location requirements of the aircraft-mounted positive pressure breathing system components. Demonstration shall verify the functionality of the positive pressure breathing system.

Pressure transducer(s) placed in the air line(s) of the human-mounted components of the positive pressure breathing system shall be used to instrument the system for test. Tests shall verify compliance with the steady-state pressurization schedule within ___10___ psi or ___11___ percent over the full specified pressure range, and shall verify that the "pressure onset" and "slope(s)" are adjustable over their specified ranges. Test shall verify that a "freeze" command results in pressure returning to that level corresponding to one g-unit. Apply a square wave (with a period at least ten times the larger of the two specified inflation-exhaust times and an amplitude corresponding to a full-range pressure change) to the system input, and verify that pressure reaches 63 percent of its final value within the times specified for both inflation and exhaust.

Inspection and analysis of vendor drawings and control mechanisms, in conjunction with hardware tests, shall verify that the human-mounted components of the positive pressure breathing system cannot be pressurized beyond the specified maximum.

RATIONALE
There is no experience basis regarding the effectiveness, or user acceptance of, simulating positive pressure breathing systems. The "requirement" and "guidance" presented here are structured around the assumption that the crewmembers' unmodified personal equipment will be used; this should in no way be construed as being the preferred design solution, however. It is possible that the primary cue that can safely be provided is mask tightening (which, in current designs, kicks in at 4 g-units). Unfortunately, the manifolding on current human-mounted equipment has only a single pressurized air input. Providing mask-tightening cues without pressurizing the jerkin bladder or the breathing air would probably entail the design of simulator-specific personal equipment.

Requirements Guidance:
If actual jerkin bladder and breathing air pressurization and mask tightening is not required, delete all but the first sentence. If simulator-specific personal equipment is to be used, add a requirement to provide an appropriate quantity with the simulator and replace the proposed performance specifications with specifications relevant to that design.

Blank (1) should specify the aircrew positions for which pressure and mask tightening cues are to be simulated. In a multiple-place aircraft, there may be little benefit to fully simulating these systems for crewmembers who are not piloting the aircraft (although there may be training benefit in providing connections and functioning controls and displays for all crewmembers).

Blank (2) should specify the maximum permissible pressure. Pressures used in an actual high-g environment can be dangerous in a one-g environment. In past simulators, the maximum pressure used in anti-g suit simulations has typically been specified at 7 psi. This value is probably far too high for breathing air and jerkin bladder pressurization. Safety Engineering should be consulted regarding acceptable values.

Based upon experience with past anti-g suit pressurization schedule preferences, it is recommended that the "onset" and "slope" of the pressurization schedule be adjustable over a fairly wide range. Some anti-g suit simulation users have even found it useful to set these such that there is a residual pressurization at the simulated one-g level, so that negative g-loading cues could be provided. Pressure "onset" should be adjustable over a range up to at least +4 g-units (the mask tightening threshold on current aircraft implementations). The "slope" has been adjustable over a range of 0.5 to 1.5 psi/g in anti-g suit simulation systems with a maximum pressure of 7 psi; lower values will probably be suitable for positive pressure breathing system simulations, but have yet to be determined. Once determined, specify the required pressure onset range in blanks (3) and (4) and the required slope in blanks (5) and (6).

Verification Guidance:
If actual positive pressure breathing system pressurization is not required, delete all but the first paragraph and place "inspection and demonstration" in blank (9).

If simulator-specific personal equipment is to be used, tailor the verification requirements to the new performance specifications.

If pressurization of the human-mounted components of the positive pressure breathing system is required, place "inspection, analysis, demonstration, and test" in blank (9). Blanks (10) and (11) specify the tolerance for compliance with the required steady-state pressurization schedule. Since the crewmember(s) will be more sensitive to pressure changes than to steady-state pressures, this tolerance need not be overly restrictive; tolerance values on the order of 0.1 psi (this value will depend upon the specific design, and should not be used blindly) for blank (10) and 20 percent for blank (11) would be reasonable.

Process Guidance:
Since there is no precedent for positive pressure breathing simulation, a process should be defined which results in: (1) candidate design solutions being prototyped and demonstrated with the user, and (2) documentation of acceptable performance characteristics, and their incorporation into the approved design criteria. Since there are safety issues, this process must involve Safety Engineering. Armstrong Laboratory support should be solicited to support the prototyping effort and the investigation of safety concerns.

3.7.3.6.3.1.3 Eye Protection. The LASER eye protection system shall be simulated in accordance with the approved design criteria.

4.2.1.7.3.6.3.1.3 Verification of Eye Protection. This requirement shall be verified by ____1____.

RATIONALE
Verification Guidance:
Fill in blank (1) with "demonstration" or "test", then provide details regarding the particular verification method. Normally demonstration of the eye protection system to subject matter experts should suffice.

3.7.3.6.3.2 Storage Space for Personal Equipment. Storage space for personal equipment shall be provided as in the aircraft, in accordance with the approved design criteria.

4.2.1.7.3.6.3.2 Verification of Storage Space for Personal Equipment. This requirement shall be verified by inspection.

RATIONALE

Requirements Guidance:
If storage space for personal equipment is not required, replace the proposed wording with "This requirement is not applicable."

Verification Guidance:
Inspection should be adequate to assure compliance with this requirement. If this requirement is not applicable, replace the proposed wording with "Verification of this requirement is not applicable."

3.7.3.6.3.3 Night Vision Systems/Helmet Mounted Displays. The ___1___ shall be simulated in accordance with the approved design criteria. ___2___.

4.2.1.7.3.6.3.3 Verification of Night Vision Systems/Helmet Mounted Displays. This requirement shall be verified by ____3____.

RATIONALE

Requirements Guidance:
It is recommended that the title of this paragraph be tailored to represent the type of helmet-mounted system to be simulated. Blank (1) should identify the system to be simulated. Blank (2) should provide any additional clarification or extension of the requirement, including level of fidelity and quantities to be furnished with the simulator. This requirement should be limited to that equipment located within the air vehicle; requirements such as those specific to image generation and display systems belong under paragraph 3.7.2 "Cue Generators". See the example provided. Subparagraphs may be included to aid clarity.

Verification Guidance:
Fill in blank (3) with "inspection", "analysis", "demonstration", or "test", as appropriate to assure compliance with the requirement. For other than "inspection", treat the first sentence as a paragraph lead-in and provide details regarding the particular verification method. See the example provided.

Process Guidance:
If appearance or function of the equipment is permitted to deviate somewhat from the actual equipment being simulated (as in the example provided), a process needs to be defined which will capture the required appearance and/or function in the approved design criteria. The user must be involved in this process.

EXAMPLES
For a device in which the Night Vision Goggle simulation incorporates a built-in visual display system, the following might apply.

3.7.3.6.3.3 Night Vision Goggles (NVGs). The model ANVIS-6 Night Vision Goggle (NVG) system shall be simulated in accordance with the approved design criteria. The simulated NVGs shall appear similar to the actual equipment, as defined in the approved design criteria. The simulated NVGs shall mount to a helmet so as to be active in a flipped-down position and stowable in a flipped-up position. The simulated NVGs shall function in accordance with the approved design criteria. Simulated NVGs shall be provided for three crewmembers: the Aircraft Commander, Copilot, and Flight Engineer.

3.7.3.6.3.3.1 NVG Weight and Center of Gravity. Weight of the simulated NVGs shall not be more than 1200 grams greater than that of the actual NVGs. The center of gravity of the simulated NVGs shall be symmetric laterally and within 50 millimeters of the actual NVGs longitudinally.

3.7.3.6.3.3.2 NVG Operational Envelope. The operational envelope of each simulated NVG shall accommodate a volume 60 inches wide by 30 inches high by 40 inches deep. Each NVG's position shall be sensed to an accuracy of at least 0.14 degrees angularly and 0.15 inches translationally throughout its operational envelope.

3.7.3.6.3.3.3 NVG Field-of Regard. The viewable field-of-regard shall encompass the entire solid angle surrounding the user's eyepoint, except as would be obstructed by cockpit and airframe structures.

4.2.1.7.3.6.3.3 Verification of Night Vision Goggles (NVGs). This requirement shall be verified by inspection and demonstration. Inspection shall verify compliance with appearance and location requirements. Demonstration shall verify compliance with the functional requirements.

4.2.7.3.6.3.3.1 Verification of NVG Weight and Center of Gravity. This requirement shall be verified by analysis and test. Analysis shall verify compliance with the center of gravity requirement. Test shall verify compliance with the weight requirement.

4.2.7.3.6.3.3.2 Verification of NVG Operational Envelope. This requirement shall be verified by test. Test shall verify compliance of each NVG with the sensor accuracy requirement throughout the operational envelope for the full field of regard.

4.2.7.3.6.3.3.3 Verification of NVG Field-of Regard. This requirement shall be verified by demonstration.

3.7.3.6.4 Seating. Seats shall be provided for each crewmember which appear and function equivalently to those in the aircraft, in accordance with the approved design criteria.

4.2.1.7.3.6.4 Verification of Seating. This requirement shall be verified by ____1____.

RATIONALE

Requirements Guidance:
For most seating requirements (including body positioning seats designed to afford high-g protection), the proposed wording should suffice. However, it may be sufficient (and may sometimes be preferable, from both a cost and training perspective) to have seats which do not appear or function as the aircraft seats. Tailor this requirement to be consistent with what is actually needed.

Do not overlook the possibility of a requirement for an additional (jump) seat for an instructor or observer in the crewstation area. When an observer is to be onboard a cockpit on a motion platform, for example, accommodation must be made for the observer's being seated and belted in whenever the cockpit is in motion. The type and location of an instructor/observer seat must be specified, along with any requirements for safety restraints, in addition to the proposed requirement wording.

Verification Guidance:
Fill in blank (1) with "inspection" and "demonstration" as applicable. Inspection should be sufficient to verify seat location and appearance. Demonstration may be needed to assure that the seats function as required.

3.7.3.7 Weapons/Stores Simulation. The aircraft stores management system __1__.

The simulated aircraft shall carry __3__.

The simulated aircraft shall carry __4__.

The weapons shall __6__.

4.2.1.7.3.7 Verification of Weapons/Stores Simulation. This requirement shall be verified by test. Each required weapon shall be launched.

RATIONALE
This paragraph identifies the weapons to be carried on the simulated aircraft and the fidelity of the simulation of the weapon while it is carried on the simulated aircraft. It also covers the fidelity of the simulation of the aircraft's stores management system. It does not cover any aspects of weapon

simulation once the weapon is launched, nor does it cover the fidelity of simulation of weapons launched against the simulator.

Requirements Guidance:

1. *Fill in the blank with one of the following:*

a. "shall be replicated. The simulator shall provide performance identical to that of the aircraft stores management system as defined by the design criteria and limited by other requirements of this specification across the entire operating spectrum of the aircraft."

b. "shall be partially replicated. The simulator shall provide performance identical to that of the aircraft stores management system or particular subsystem as defined by the design criteria and limited by other requirements of this specification except __2__."

c. "is not required. No simulation is required except that necessary to provide the nominal inputs necessary for other systems or subsystems to meet the requirements of this specification."

2. *If b is used in blank (1), specify the exceptions to full simulation of the stores management system.*

3. *Fill in the blank with "the weapons identified in accordance with the statement of work", or "all weapons carried by the aircraft, as identified by design criteria", or identify the actual weapons to be simulated.*

4. *Fill in the blank with "all combinations of weapons for which the aircraft (5) is certified, as identified by design criteria", or list the specific stores configuration required.*

5. *If certification has not occurred use "will be" instead of "is" in blank (4).*

6. *Choose from the following list as applicable.*

a. Affect the signature of the simulated vehicle as seen by entities. This shall include changes to the signature as bay doors are opened or weapons are released.

b. Affect the weight, balance, and performance of the simulated air vehicle as weapons are carried or released.

c. Interact with the simulated stores management system as required to provide the fidelity specified herein.

EXAMPLES
3.7.3.7 Weapons/Stores Simulation. The aircraft stores management system shall be partially replicated. The simulator shall provide performance identical to that of the aircraft stores management system or particular subsystem as defined by the design criteria and limited by other requirements of this specification except that no AIM-9 video need be displayed in the cockpit. The simulated aircraft shall carry the following weapons: AIM-9L, AIM-7F, AIM-120, and M-63 Gun. The simulated aircraft shall carry all combinations of weapons for which the aircraft will be certified, as identified by design criteria. The weapons shall:

a. Affect the signature of the simulated vehicle as seen by entities. This shall include changes to the signature as bay doors are opened or weapons are released.

b. Affect the weight, balance, and performance of the simulated air vehicle as weapons are carried or released.

c. Interact with the simulated stores management system as required to provide the fidelity specified herein.

3.7.4 Simulation Control and Monitoring. (1)Simulator controls shall permit all events and activities required by this specification to be commanded. A display system integrated with the controls shall facilitate control use and afford the monitoring of crewmember performance. The simulation control and monitoring system shall permit __2__ to readily ascertain the current simulator mode, and the status of all events and activities required by this specification. The simulation control and monitoring system shall be __3__.

4.2.1.7.4 Verification of Simulation Control and Monitoring. This requirement shall be verified by analysis and test. Analysis during design reviews shall verify that the simulation control and monitoring system will operate under all conditions required by this specification. Test shall verify that:

a. All required events and activities are commanded as required by this specification.

b. All required information can be displayed.

RATIONALE
In most traditional simulators, this section has been entitled "Instructional System". The name has been changed because not all simulators use instructors (e.g., some training devices are self-paced and mission rehearsal devices typically use operators), and much simulation control is accomplished automatically via mission scripts. In addition, many requirements that used to reside under "Instructional System" (such as record, playback, and malfunctions) have been moved to other areas.

This is an introductory paragraph to establish the top-level requirements for simulator mode, event, and activity monitoring and control. The more detailed requirements are defined in the subparagraphs of this section. Display requirements associated with control requirements (e.g., a display at one instructor console indicating that another instructor console has control) are included with the relevant control requirement. Display requirements associated with monitoring simulation events and activities and with monitoring student performance are included under "monitoring" requirements.

Requirements Guidance:

1. Delete or tailor the two sentences following (1) if the requirement is different for the specific application.

2. Specify the number of persons who will be using the monitoring system and who they will be (e.g., instructor, operator, etc.).

3. State where the control and monitoring system is to be located. Often it is integrated into the instructor station/console.

EXAMPLES
3.7.4. Simulation Control and Monitoring. Simulator controls shall permit all events and activities required by this specification to be commanded. A display system integrated with the controls shall facilitate control use and afford the monitoring of crewmember performance. The simulation control and monitoring system shall permit a single instructor to readily ascertain the current simulator mode, and the status of all events and activities required by this specification. The simulation control and monitoring system shall be integrated into the instructor station.

3.7.4.1 Simulation Control. Simulation control shall be:

a. (1) Automatic, based on simulator mission scripts. All events and activities required by this specification shall be automatically controlled, (2) except for __2a__.

b. Manual, via __3__ control. Manual control shall automatically override the simulator mission script, (4) except for __4a__. However, the effect of the override shall be limited to events that are directly affected by the manual control. (5)All events and activities required by this specification shall be manually controlled, (6) except for __6a__.

c. (7) By other simulators in an interactive operation. Manual and automatic control shall be disabled for any part of the synthetic environment controlled by other simulators. Changes to any part of the synthetic environment controlled by this simulator shall be transmitted to the other simulators involved in interactive operation.

d. Built directly into the simulation when required by this specification.

__8__.

4.2.1.7.4.1 Verification of Simulation Control. This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that the simulation control system design is consistent with the requirement. Demonstration, in conjunction with other verification activities required by this specification, shall verify that simulation control system performance is compliant with the requirement.

RATIONALE
This paragraph defines simulator control requirements and display requirements associated with simulator control (but not display requirements associated with simulation events and activities or with student performance monitoring).

Requirements Guidance:

1. Delete the paragraph following (1) if automatic simulation control is not required.

2. If there are no exceptions to the events and activities that are subject to automatic control, delete the phrase following (2). Otherwise, state any exceptions to automatic simulation control in blank (2a).

3. State who will perform the control; usually this will be the instructor or operator conducting the exercise.

4. If there are no exceptions to manual control override, delete the phrase following (4). Otherwise, state any exceptions to manual control override in blank (4a).

5. Tailor the sentence following (5) if the requirement is different for the specific application. In general, use of manual control in a highly automated exercise can result in inconsistencies.

6. If there are no exceptions to the events and activities that are subject to manual control, delete the phrase following (6). Otherwise, state any exceptions to manual simulation control in blank (6a).

7. Delete the paragraph following (7) if interactive operation is not required.

8. Discuss any requirements for override when multiple controls provide the same commands, or for the operation of simulation control in multi-station operating mode, etc.

EXAMPLES
Example 1. System specification for a simulator, with onboard and remote instructor stations, that requires automatic control.

3.7.4.1. Simulation Control. Simulation control shall be:

a. Automatic, based on simulator mission scripts. All events and activities required by this specification shall be automatically controlled, except for mode selection, halt, and crash override.

b. Manual, via instructor control. Manual control shall automatically override the simulator mission script. However, the effect of the override shall be limited to events that are directly affected by the manual control. All events and activities required by this specification shall be manually controlled.

c. Built directly into the simulation when required by this specification.

When the onboard instructor console is in use, this fact shall be continuously indicated at the remote instructor console.

Example 2. PIDS requirement for a mission rehearsal device with tailored automatic control.

3.7.4.1. Simulation Control. Simulation control shall be:

a. Automatic, based on simulator mission scripts. All events and activities required by this specification shall be automatically controlled.

b. Manual, via mission rehearsal operator control. Manual control shall automatically override the simulator mission script. However, the effect of the override shall be limited to events that are directly affected by the manual control. All events and activities required by this specification shall be manually controlled, except for those associated with the atmospheric simulation required by this specification.

c. Built directly into the simulation when required by this specification.

Example 3. PIDS requirement for a self-paced simulator with no automatic control.

3.7.4.1. Simulation Control. Simulation control shall be manual, via instructor control, and built directly into the simulation when required by this specification.

Example 4. System specification requirement for a multi-station simulator with two instructor stations and automatic control.

3.7.4.1. Simulation Control. Simulation control shall be:

a. Automatic, based on simulator mission scripts. All events and activities required by this specification shall be automatically controlled, except for mode selection, halt, and crash override

b. Manual, via instructor control. Manual control shall automatically override the simulator mission script. However, the effect of the override shall be limited to events that are directly affected by the manual control. All events and activities required by this specification shall be manually controlled, except for those associated with the atmospheric simulation required by this specification.

c. Built directly into the simulation when required by this specification.

Separate mission scripts shall control the simulation exercise at each student station. Each instructor station shall control any selected student station or any combination of student stations. The display system at each instructor console shall continuously indicate the student stations that are being controlled. Controls at each instructor console shall allow it to assume control of a student station currently controlled by the other instructor console when consent is requested and given through that instructor console's simulation control system.

3.7.4.1.1 Automatic Simulation Control. (1)A simulator mission script shall automatically create events (i.e., set the initial state of the simulator and change the state of the simulator) based on other events and activities, including mission time changes. The simulator mission script shall allow the creation of events based on: (2)

a. Single events and activities.

b. Logical combinations of events and activities (e.g., event_A AND event_B, event_A OR event_B, NOT event_C).

c. The state of a simulated parameter exceeding or falling within a specified limit (e.g., altitude > 10000 feet).

d. Pseudo-random numbers.

e. Logical combinations of the above.

The __3__ shall be warned in regard to the next event or activity to be commanded by the simulator mission script sufficiently in advance to permit action to be taken to override it. If a specific event or activity cannot be deterministically predicted, then the warning shall apply to the most-probable next event or activity. The simulation control system shall permit __4__ to modify the events of a simulator mission script prior to any exercise.

4.2.1.7.4.1.1 Verification of Automatic Simulation Control. This requirement shall be verified by analysis and test. Analysis during design reviews shall verify that the automatic simulation control system design is consistent with the requirement. Test, using an actual simulator mission script, shall verify that events are initiated in accordance with the requirement. Test shall also verify warning and event override and modification.

RATIONALE
This paragraph defines automatic simulator control requirements and display requirements associated with automatic simulator control (but not display requirements associated with simulation events and activities or student performance).

Requirements Guidance:

1. Delete the entire paragraph if automatic simulation control is not required.

2. Delete any enumerated items a to e which are not required.

3. Specify who will be warned; usually this will be the instructor or operator conducting the exercise.

4. Specify who will perform the modification; usually this will be the instructor or operator conducting the exercise.

EXAMPLES
3.7.4.1.1 Automatic Simulation Control. A simulator mission script shall automatically create events (i.e., set the initial state of the simulator and change the state of the simulator) based on other events and activities, including mission time changes. The simulator mission script shall allow the creation of events based on:

a. Single events and activities.

b. Logical combinations of events and activities (e.g., event_A AND event_B, event_A OR event_B, NOT event_C).

c. The state of a simulated parameter exceeding or falling within a specified limit (e.g., altitude > 10000 feet).

d. Pseudo-random numbers.

e. Logical combinations of the above.

The instructor shall be warned in regard to the next event or activity to be commanded by the simulator mission script sufficiently in advance to permit action to be taken to override it. If a specific event or activity cannot be deterministically predicted, then the warning shall apply to the most-probable next event or activity. The simulation control system shall permit a simulator instructor to modify the events of a simulator mission script prior to any exercise.

3.7.4.1.2 Manual Simulation Control. (1)Manual Simulation Control shall meet all requirements of this specification and shall: (2)

a. Accommodate loading of aircraft operational flight programs __3__.

b. Allow __4__ to take control of __5__ to demonstrate operation from __6__.

c. Allow __4__ to play the role of crewmembers not present in the simulator for purposes of interphone communications.

d. Allow the __4__ to manually control entities in the environment __7__.

e. Acknowledge data entry and discrete control input actions within __8__.

4.2.1.7.4.1.2 Verification of Manual Simulation Control. This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that the manual simulation control system design is consistent with the requirement. Demonstration, in conjunction with other verification activities required by this specification, shall verify that manual simulation control system performance is compliant with the requirement.

RATIONALE
This paragraph defines manual simulator control requirements and display requirements associated with manual simulator control (but not display requirements associated with simulation events and activities or student performance).

Requirements Guidance:

1. Delete the entire paragraph if there are no special manual simulation control requirements.

2. Delete any enumerated items a through e that are not required, or tailor as necessary.

3. State where the operational flight programs will be loaded. If they are loaded in the aircraft crew station, this requirement is not necessary.

4. State who will do the controlling. Usually this will be the instructor or operator conducting the exercise.

5. Identify the cockpit systems to be controlled.

6. State where the control will be accomplished, such as "the instructor station".

7. Identify any specific manual control features required (e.g., pilot-like controls) and where control will be accomplished.

8. Specify the maximum delay permitted before the system responds to a data entry or discrete control input action. If all processing can be accomplished within the permitted delay period, this acknowledgment may simply be an appropriate display update. If the processing time required exceeds the permitted delay period, this acknowledgment would indicate that the input was recognized and processing is in-progress (with an appropriate indication of the delay for completion of the required processing such as the display of an hourglass icon or a progress bar). The permitted delay period may be expressed in seconds, or may be "the Maximum Software Transport Delay allowed by this specification". In general, delays in computer response feedback should not exceed 0.2 seconds (see "Guidelines for Designing User Interface Software", ESD-TR-86-278).

Process Guidance: *Sufficient information to make intelligent decisions on the various control requirements may not be available at the start of development. If both a system specification and PIDS are used on a program, then this paragraph need not be included in the System Specification. If only one specification is used for the device, then it may be necessary to make this requirement "TBD" and define a statement of work process to rewrite it later. If both specifications are used, the statement of work should task development of the applicable PIDS requirement.*

EXAMPLES
3.7.4.1.2 Manual Simulation Control. Manual Simulation Control shall meet all requirements of this specification and shall:

a. Accommodate loading of aircraft operational flight programs using the actual aircraft data cartridge through a terminal near the operator's station similar to the actual aircraft wheel-well terminal.

b. Allow an instructor to take control of the simulated aircraft radar to demonstrate operation from the instructor station.

c. Allow the operator to play the role of crewmembers not present in the simulator for purposes of interphone communications.

d. Allow the operator to manually control entities in the environment using a stick, throttles, and an entity out-the-window scene displayed at the operator station.

e. Acknowledge data entry and discrete control input actions within 200 milliseconds.

3.7.4.2 Simulation Monitoring. (1)Simulation monitoring shall meet all requirements of this specification and shall: (2)

a. Display dynamic pictorial representations of __3__.

b. Display information to provide __4 __ situational awareness regarding entities in the simulated environment. __5__

c. Repeat the out the window visual display.

d. Repeat the __6__.

4.2.1.7.4.2 Verification of Simulation Monitoring. This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that the simulation monitoring system design is consistent with the requirement. Demonstration, in conjunction with other verification activities required by this specification, shall verify that simulation monitoring system performance is compliant with the requirement.

RATIONALE
This paragraph defines display requirements associated with monitoring simulation events and activities and student performance.

Requirements Guidance:

1. Delete the entire paragraph if there are no specific monitoring requirements.

2. Delete any enumerated items a-d that are not required. Tailor the requirements in items a-d as necessary, for example, if any information must be displayed continuously this must be indicated appropriately in items a-d.

3. Identify cockpit instruments and displays for which dynamic pictorial representations are to be provided.

4. State for whom the displayed information is to be provided. Usually this will be the instructor or operator conducting the exercise.

5. State any special requirements. These may include: map displays centered about the simulated aircraft; out-the-window displays from the perspective of various entities; three dimensional displays, etc.

6. State any systems for which repeaters are required (i.e., displays with fidelity identical to those used in the aircrew station).

Process Guidance: *Sufficient information to make intelligent decisions on the various display requirements may not be available at the start of development. If both a system specification and PIDS are used on a program, then this paragraph need not be included in the System Specification. If only one specification is used for the device, then it may be necessary to make this requirement "TBD" and define a statement of work process to rewrite it later. If both specifications are used, the statement of work should task development of the applicable PIDS requirement.*

EXAMPLES
3.7.4.2 Simulation Monitoring. Simulation monitoring shall meet all requirements of this specification and shall:

a. Display dynamic pictorial representations of the student-station Horizontal Situation Indicator and Attitude Director Indicator.

b. Display information to provide the instructor situational awareness regarding entities in the simulated environment. This shall include a representation of the out-the-window scene as seen from each entity representing an aircraft that the instructor can control manually.

c. Repeat the student-station radar display.

3.7.4.3 Embedded Computer Based Training. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

Simulator mission scripts shall be integrated with a computer-based training system to permit full interaction between the simulator and computer-based training lessons. Lesson material shall be displayed on __1__. The crewmember shall interact with the lesson using __2__.

-OR-

The simulator shall automatically monitor crewmember actions and compare results with correct procedures for __3__. Results shall be __4__.

4.2.1.7.4.3 Verification of Embedded Computer Based Training. This requirement shall be verified by test. Test shall verify all required features of the embedded computer-based training system.

RATIONALE
Simulators have often incorporated elements of computer-based training. Even in the early 1970s, the Simulator for Electronic Warfare Training used simulator mission scripts to monitor and grade student performance -- in addition to controlling the overall exercise. Many simulators monitor the student performance of specific procedures called out in flight manuals. The student actions relative to the procedure are compared to a checklist, and the results displayed to the instructor. Some newer simulators actually integrate computer-based training systems with simulators such that they interact dynamically.

Requirements Guidance:
Choose the first alternative if a full embedded-training computer-based system is required. Note that this paragraph does not cover the requirements for the computer-based training system -- it only includes the requirement for the simulator to interact with it. Use the second paragraph if only the monitoring of procedures is required. If neither is required, delete the paragraph.

1. Describe how lesson material should be displayed. Two possibilities are "the displays in the crew station" and "on a computer-based training terminal useable by a crewmember at his station".

2. Describe how the crewmember will interact with the computer-based training system. Some possibilities are "a portable keyboard", "actual crewstation controls", or "a keyboard located at the crewmember's station".

3. Enumerate the procedures to be monitored.

4. Describe how the results of procedures monitoring will be used. Some possibilities include:
   a. Displayed instantly to the instructor.
   b. Saved for evaluation and student debrief at the end of an exercise.
   c. Printed for post exercise critique.
   d. a and c
   e. b and c

Process Guidance: *Whether or not fully embedded training is used should be a decision resulting from the Instructional System Development process. Fully embedded training will require significant interface with courseware developers. If fully embedded training is required, the statement of work should task the contractor to interface with the courseware developer as the embedded-training student interface is refined and implemented.*

EXAMPLES
Example 1. Fully embedded computer-based training is required.

3.7.4.3 Embedded Computer Based Training. Simulator mission scripts shall be integrated with a computer-based training system to permit full interaction between the simulator and computer-based training lessons. Lesson material shall be displayed on a computer-based training terminal located in close proximity to the crewmember's station. The crewmember shall interact with the lesson using a keyboard associated with the terminal.

Example 2. Only the monitoring of crewmember procedures is required.

3.7.4.3 Embedded Computer Based Training. The simulator shall automatically monitor crewmember actions and compare results with correct procedures for all normal and emergency procedures identified in the flight manual. Results shall be displayed instantly to the instructor and printed for post exercise critique.

3.7.5 Simulation Support Systems. (1)Simulation support systems shall: (2)

a. Allow __3__ to modify simulator software.

b. Allow __3__ to perform minor modifications to simulator hardware.

c. Allow __3__ to manage the configuration of the simulator and its associated documentation.

(4)Use of the simulation support system shall not preclude simultaneous full use of the remainder of the simulator.

4.2.1.7.5 Verification of Simulation Support Systems. This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that the simulation support system design is consistent with the requirement. Demonstration shall verify that performance is compliant with the requirement.

RATIONALE
Simulation support systems can include such things as the Training System Support Center or elements of Training Management. They are usually completely independent of the simulator. When the simulator is purchased as part of a larger training system, the simulation support system may be specified independently.

Requirements Guidance:

1. Delete the entire paragraph if simulaticn support is covered in another specification.

2. Delete subparagraphs a-c as applicable.

3. Specify who will perform these tasks in blank (3). Typically this would be, "any government-selected Contractor Logistics Support (CLS) contractor".

4. Delete the sentence following (4) if the simulator may be used for its own support during periods when it is not supporting operational activities.

EXAMPLES
3.7.5. Simulation Support Systems. Simulation support systems shall:

a. Allow any government-selected Contractor Logistics Support (CLS) contractor to modify simulator software.

b. Allow any government-selected CLS contractor to perform minor modifications to simulator hardware.

c. Allow any government-selected CLS contractor to manage the configuration of the simulator and its associated documentation.

Use of the simulation support system shall not preclude simultaneous full use of the remainder of the simulator.

4.2.1.7.5. Verification of Simulation Support Systems. This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that the simulation support system design is consistent with the requirement. Demonstration shall verify that performance is compliant with the requirement.

3.7.5.1 Simulation Exercise Modification. (1)Simulation support systems shall allow __2__ to modify and create simulator mission scripts, and any associated data not included in the scripts, for the purpose of modifying any existing simulation exercise and creating new simulation exercises. (3)The creation of a new exercise shall be completed within __3a__, starting __3b__. (4)The modification of an existing exercise shall be completed within __4a__, starting __4b__. The simulation support system shall allow the creation of:

a. A totally new geographic environment within the gaming area defined by section 3.7.1 of this specification. (5)This part of the simulated environment shall be generated from __5a__.

b. A completely new set of atmospheric conditions for the exercise. (5)This part of the simulated environment shall be generated from __5a__.

c. A completely new set of entities synthesized from those identified in paragraph 3.7.1.5.6 "Entity Identification". (5)This part of the simulated environment shall be generated from __5a__.

4.2.1.7.5.1 Verification of Simulation Exercise Modification. CHOOSE ONE OF THE FOLLOWING TWO ALTERNATIVES:

This requirement shall be verified by analysis and test. Analysis during design reviews shall verify that the design is consistent with the requirement. A comprehensive test shall verify that the required users can build a complete exercise from scratch for the maximum size environment required by this specification.

-OR-

This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that the design is consistent with the requirement. Demonstration conducted in conjunction with the development of exercises necessary for required verification shall verify that performance is compliant with the requirement.

RATIONALE

Requirements Guidance:

1. Delete the entire paragraph if simulation support is covered in another specification.

2. Specify who will modify and create simulation exercises in blank (2).

3. If there is no constraint on the time required to create a simulation exercise (as would be typical for training missions), delete the sentence following (3). If there is a constraint on the time required (as may

be the case with a mission rehearsal device), retain the sentence and insert the time constraint in blank (3a). State when the time starts in blank (3b).

4. If there is no constraint on the time required to modify a simulation exercise (as would be typical for training missions), delete the sentence following (4). If there is a constraint on the time required (as may be the case with a mission rehearsal device), retain the sentence and insert the time constraint in blank (4a). State when the time starts in blank (4b).

5. Where there is no specific requirement regarding data sources, delete the sentence following (5). Otherwise identify the sources in blank __5a__.

Verification Guidance: *Choose the first alternative when simulation exercise creation and modification are critical requirements or involve a unique user (such may be the case with mission rehearsal devices). Otherwise choose the second alternative; it will be cheaper and simpler.*

Process Guidance: *When there is a requirement for the simulation support systems to accept data from a large variety of sources (e.g., Mission Rehearsal Devices may have requirements to develop synthetic environment from photographs, maps, satellite imagery, etc. -- see Example 2.), the Statement of Work should task the contractor to develop an Interface Control Document in conjunction with the government that spells out all source-data media and formats.*

EXAMPLES
Example 1. A specification for a weapons system trainer.

3.7.5.1. Simulation Exercise Modification. Simulation support systems shall allow government simulator operators and CLS technicians to modify and create simulator mission scripts, and any associated data not included in the scripts, for the purpose of modifying any existing simulation exercise and creating new simulation exercises. The simulation support system shall allow the creation of:

a. A totally new geographic environment within the gaming area defined by section 3.7.1 of this specification. This part of the simulated environment shall be generated from data supplied from the Standard Simulator Data Repository.

b. A completely new set of atmospheric conditions for the exercise.

c. A completely new set of entities synthesized from those identified in paragraph 3.7.1.5.6 "Entity Identification".

4.2.1.7.5.1 Verification of Simulation Exercise Modification. This requirement shall be verified by analysis and demonstration. Analysis during design reviews shall verify that the design is consistent with the requirement. Demonstration conducted in conjunction with the development of exercises necessary for required verification shall verify that performance is compliant with the requirement.

Example 2. A specification for a Mission Rehearsal Device.

3.7.5.1. Simulation Exercise Modification. Simulation support systems shall allow government and CLS technicians to modify and create simulator mission scripts, and any associated data not included in the scripts, for the purpose of modifying any existing simulation exercise and creating new simulation exercises. The creation of a new exercise shall be completed within 48 hours, starting when the geographic area of interest is identified to the contractor by the Air Force Project Officer. The modification of an existing exercise shall be completed within four hours, starting when updated intelligence data are provided to the contractor by the Air Force Project Officer. The simulation support system shall allow the creation of:

a. A totally new geographic environment within the gaming area defined by section 3.7.1 of this specification. This part of the simulated environment shall be generated from any provided hardcopy data (e.g., maps and photographs), and from any digitally stored data-source having data and media formats complying with the Interface Control Document.

b. A completely new set of atmospheric conditions for the exercise. This part of the simulated environment shall be generated from meteorological forecasts of weather conditions.

c. A completely new set of entities synthesized from those identified in paragraph 3.7.1.5.6 "Entity Identification". This part of the simulated environment shall be generated from current intelligence data.

4.2.1.7.5.1 Verification of Simulation Exercise Modification. This requirement shall be verified by analysis and test. Analysis during design reviews shall verify that the design is consistent with the requirement. A comprehensive test shall verify that the required users can build a complete exercise from scratch for the maximum size environment required by this specification.

3.8 Precedence. Precedence shall be as ______________.

4.2.1.8 Verification of Precedence. Verification of this requirement is not applicable.

RATIONALE
MIL-STD-490B states that, "This paragraph of the specification shall specify the order of precedence of requirements, such as the specification over drawings, functional requirements over physical requirements, adherence to specified processes over other requirements, etc. This paragraph shall also specify that the requirements of the specification shall take precedence over any referenced documents."

Requirements Guidance: *The above MIL-STD-490B citation notwithstanding, it is generally better practice to define precedence in the contract. The usual order of precedence is as follows:*

a. The statement of work tasks that a system be built to meet a top level specification and has the highest precedence of any contract document. The top level specification could be a weapons system specification, a training system specification, a flight simulator system specification, or even a flight simulator prime item development specification.

b. The top level specification takes precedence over any lower tier program specifications. Tiering may cover multiple levels with the higher tier taking precedence.

c. All specifications take precedence over standards referenced therein.

Note, however, that it is foolish to rely on precedence. Program teams must ensure that their documentation is consistent. Lower tier specifications can be considered interpretations of higher level specifications (e.g., the top level specification may require that a system operate in a standard office environment and the lower level specification may interpret that environment by requiring that the system operate from 20 to 25 degrees C). If the government accepted the lower level specification, it would be in a poor position to require that the system operate over a larger temperature range. When a Military Standard or other document is referenced, it is very important that the reference be very specific. For example, do not state that "User-computer interface shall be in accordance with MIL-STD-1472" unless you want every requirement of that standard to apply. If you make this statement, do not reference other standards unless you know they are consistent. Do not make statements about log-in procedures, processing delay, units, etc., in the specification and rely on precedence to resolve issues. Make explicit references (e.g., processing delay shall be in accordance with paragraph 5.15.9 of MIL-STD-1472).

Where a Systems Requirement Document (SRD) is used, the SRD has no precedence. The specifications should cover the program once a contract is awarded; they replace the SRD. When

specifications are required in a source selection, they are evaluated for conformance with the SRD. After a contract award the SRD should cease to exist.

EXAMPLES
3.8 Precedence. Precedence shall be as defined in the contract.

4. QUALITY ASSURANCE PROVISIONS.

RATIONALE
This is a title only paragraph

4.1 General. Requirements shall be verified by one or more of the following methods:

a. Inspection: A visual observation of equipment, drawings, or documentation to assure a requirement has been met.

b. Analysis: A detailed review of data or test results to assure a requirement has been met. This includes analysis of design data during the development process.

c. Demonstration: Exercise of equipment to assure a requirement has been met. No detailed procedure is required.

d. Test: Use of equipment under controlled conditions in conjunction with a detailed test procedure to assure a requirement has been met.

Performance shall meet the approved design criteria within the tolerances specified in this specification. These tolerances shall apply throughout the entire range of operation, and at any place the values may be read. Unless otherwise specified, these tolerances shall be construed to mean plus or minus values. Where a relative (percentage) tolerance is paired with an absolute (unitage) tolerance, the less restrictive of the two shall apply to any particular measurement.

In all cases the method of verification shall successfully verify that the requirement has been met, i.e. the simulator performs as required by this specification. Where the verification (Section 4) paragraph states that "this requirement is not applicable", no verification of the corresponding requirements (Section 3) paragraph is required.

RATIONALE
This specification standardizes definitions for methods used to verify simulator requirements. Its purpose is to clearly scope Development Test and Evaluation activities rather than let them be defined in a test procedures document. In many cases it will be appropriate for a user of this document to change the recommended methods of verification or to fill in a blank in which case the above definitions should be used.

In choosing methods for verification the following criteria should be used:

a. Inspection: Compliance with the requirement can be simply observed with little potential for interpretation artifacts, e.g. paint color, computer programming language, or simulator configuration.

b. Analysis: Compliance with the requirement must be derived from design data or test results. The result is not immediately obvious. This method implies Air Force agreement with the methods of analysis (i.e. how the final conclusions are reached). In many cases these analyses should be done as part of the normal development and design review process.

c. Demonstration: Compliance with the requirement must be verified by operation of the equipment. The operation requires no detailed setup, and results do not require complex or detailed evaluation.

d. Test: Compliance with the requirement is verified by system operation. A complex setup or a detailed evaluation of results is required.

Interpretation of tolerance values should remain consistent with the general statement included in this paragraph -- and need not be repeated -- unless specific exceptions are necessary (e.g., there may be instances where the tolerance band is not symmetrical about the nominal value, and specific plus and minus values must be provided).

Relative and absolute tolerance values are often paired in order to provide a minimum tolerance threshold and avoid instances where relative tolerance values alone would become unnecessarily restrictive (such as measurements taken near or at zero).

Where a verification (Section 4) paragraph states that "verification of this requirement is not applicable" , the requirements (Section 3) paragraph should be either a "title only" paragraph, a lead-in paragraph to various subparagraphs which have their own verifications, or be adequately verified by verification of other specification requirements.

***Process Guidance:** Simulator testing in the areas of handling qualities, sensor presentations and instructor console displays is often very subjective. This is partially due to the difficulties in establishing meaningful quantative requirements, as well as the need to satisfy the ultimate user (the crew members and instructors who use the device). One goal of the system engineering process must be to converge expectations with respect to these subjective areas prior to beginning the verification process. It is not acceptable for the government to use verification activities to decide what they like. The Statement of Work must address how convergence is to occur. Some suggestions are:*

a. Documentation of agreements through lower tier specifications, meeting minutes, or approved design criteria.

b. Rapid prototyping of key subjective areas.

c. Establishment of working groups, similar to cockpit review teams, to resolve subjective issues.

d. Preliminary user evaluations prior to final testing.

This specification spells out very specific verifications for each requirement. It is envisioned that some of these requirements will not be evaluated in a formal test period but will be instead verified as part of the ongoing design. A record should be maintained indicating how and when each verification was accomplished.

4.1.1 Responsibility for Verifications.

RATIONALE

Current thinking in the simulator community, represented by the ASD/YT Test 2000 Initiative, is to maximize the contractor's responsibility for test and to accept contractor test results as part of a Functional Configuration Audit at which the government makes a determination as to whether requirements are met. An evaluation of the simulator by aircrews, however, is an essential part of a Development Test and Evaluation (DT&E) Program for simulators. The government must retain responsibility for arranging and managing this portion of the DT&E Program. There may be other tests that the government wishes to perform, but these should be minimized. The contractor should be responsible for all maintenance and support of the simulator during DT&E. The Statement of Work should define these responsibilities.

4.2 System Quality Conformance Inspections.

4.3 Prime Item Quality Conformance Inspections.

RATIONALE
This is a title only paragraph.

5. PREPARATION FOR DELIVERY.

RATIONALE
The contractor is usually tasked to deliver the simulator to government operating locations. He is usually responsible for arranging the transportation. Occasionally government aircraft are used for shipping and special packing requirements may be necessary. Changes in delivery sites or methods are not infrequent and the same type of simulator may be delivered to many sites. It is recommended that the above specification wording be used to maximize contractor flexibility and responsibility for delivery as well as to eliminate the necessity to change the specification with changes in delivery sites or methods.

6. NOTES.

RATIONALE
Guidance: